Large suburban and bush Tasmanian Blue Gums (*Eucalyptus globulus*) and Black Gums (*Eucalyptus ovata*) in Mount Nelson, Tasmania, as foraging resources for the endangered Swift Parrot (*Lathamus discolor*).

by

Marta Piech

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

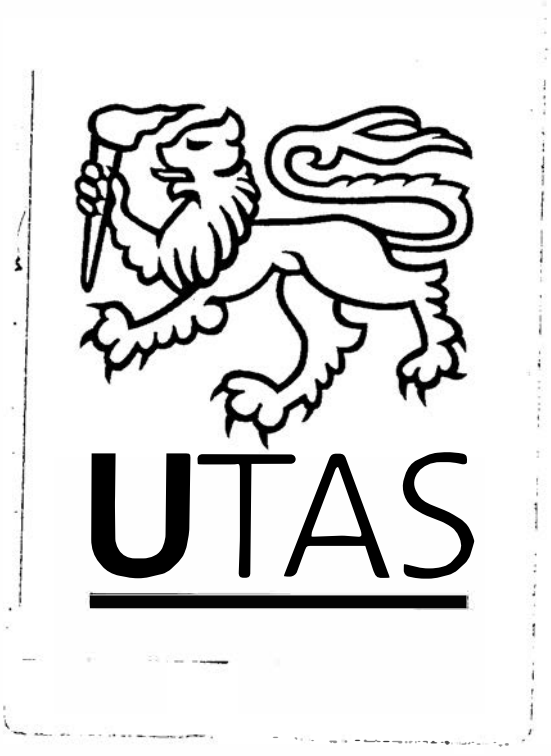
Marta Piech

15th October 2008

Dedication

This thesis is dedicated to my parents, Beata and Ryszard Piech, as well as my sister, Ula Piech.

Pracę tą dedykuję moim rodzicom, Beacie i Ryszardowi Piech, jak również mojej siostrze, Uli Piech.



Abstract

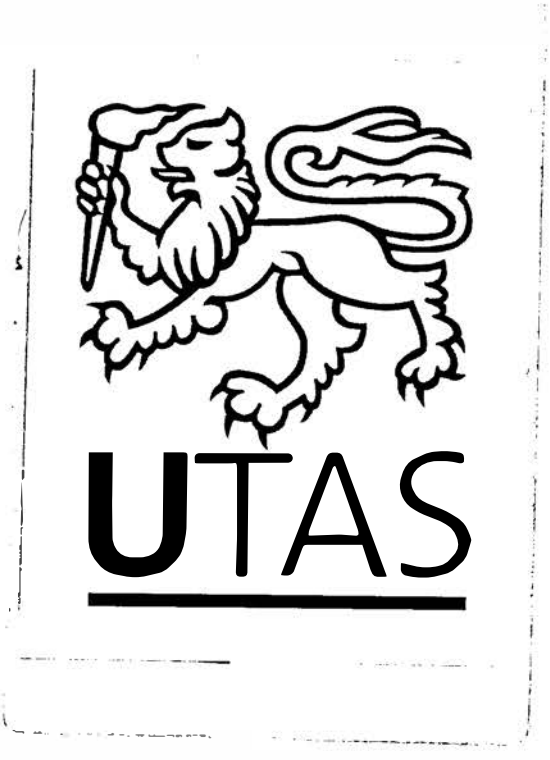
Remnant trees in suburban areas constitute potential habitat for vertebrates by providing food and nesting sites. Trees, including the Tasmanian Blue Gum (*Eucalyptus globulus*) and Black Gum (*E. ovata*), are known to supply nectar and pollen to the endangered Swift Parrot (*Lathamus discolor*), whose breeding success depends on flowering of these two eucalypt species. The outer Hobart suburb of Mount Nelson, Tasmania, is one of the foraging grounds that the Swift Parrot utilises during its breeding season.

The aim of the project was to investigate the relative value of large *E. globulus* and *E. ovata* in the bush and suburban areas of Mount Nelson as foraging habitat for Swift Parrots, and to examine which characteristics of the trees and their location affected flower production. In addition, the study investigated the recent and current trends of tree removal from private properties, as well as future plans for tree felling, in order to determine whether the forage sources for the Swift Parrot are declining within the suburb.

From a sample of 261 randomly selected large *E. globulus* and *E. ovata* trees ($\geq$ 60 cm in diameter at breast height) in Mount Nelson, it was found that suburban trees produced more flowers than their edge or bush counterparts. Hence, the former are more reliable nectar and pollen sources for a range of nectarivorous birds, including the Swift Parrot. It is thus argued that suburban trees do not just provide a secondary (to bushland) food supply for Swift Parrots, but constitute an important foraging habitat in their own right outside bush areas. Bush trees, however, despite being less important in providing food to the Swift Parrot, were more likely to support a greater number of nesting hollows for the species.

The study found that the abundance of flowers produced was significantly related to a number of tree variables. Trees with denser canopies, of better health, with no or a low percentage of branches in the canopy that were dead, and no fire damage were likely to support more flowers. The impact of fire was at least partially mediated via its effect on increasing tree dieback and the percentage of branches that were dead, and to a lesser degree, reducing canopy density.

A survey of Mount Nelson residents suggests that many large *E. globulus* and *E. ovata* occur on private unprotected land of Mount Nelson. However, they are rapidly being removed. An estimated 28.8% of all large *E. globulus* declared in the survey and 29.9% of *E. ovata* have either been removed in the past five to ten years, or will be removed in the near future. Hence, the amount of food available to Swift Parrots in Mount Nelson is being reduced. There is thus a need to retain these valuable tree resources. Maintaining trees in the suburbs as foraging habitat, as well as trees in the bush as nesting habitat, could be important for the long-term survival of the Swift Parrot.



(Photograph: Author)

" The problems do not lie with the trees; the problems lie with people: people who plant themselves amongst the trees and people who plant the trees amongst the people."

(Fakes, 1986, 48)

Acknowledgments

First of all, I would like to thank Andrew Hingston for all his time dedicated to this project, his enormous help, patience and constructive criticism. I am grateful to Andrew for his enthusiasm and optimism, and for directing me towards this very rewarding topic. This whole project would not have been possible without him.

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I want to say 'thank you' to Matt Bridges for his patience in putting up with my grumpiness and absence caused by the two years of 'isolation at the other end of the house'. Thanks go to Matt also for his support and words of encouragement during the course of my studies, and all the cups of tea that he made for me in that time.

I would also like to thank all my close friends who were always there for me and encouraged me every step of the way, even though I was sometimes too busy to see them or talk to them. A very special 'thank you' goes to Marian van den Byllaardt, whose support will not be forgotten.

Last but not least, I would like to thank my parents, Beata and Ryszard Piech, without whom I would not be where I am now. They have always wanted me to finish my degree, so here it is! This one is for you!

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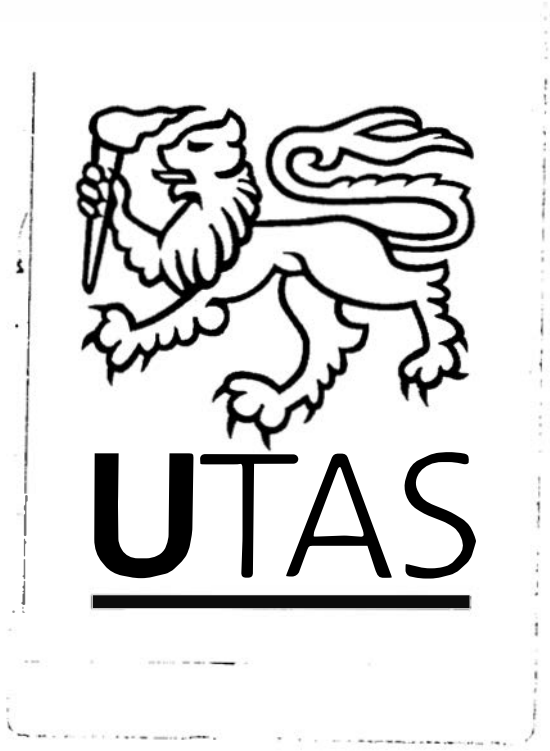

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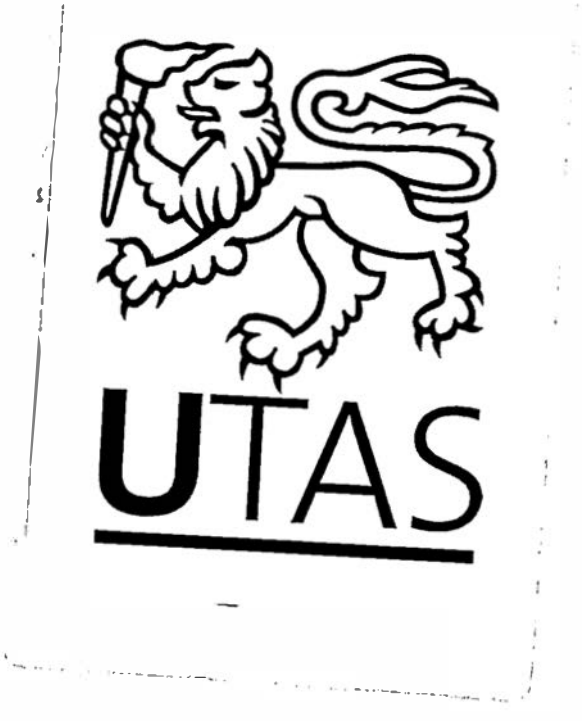

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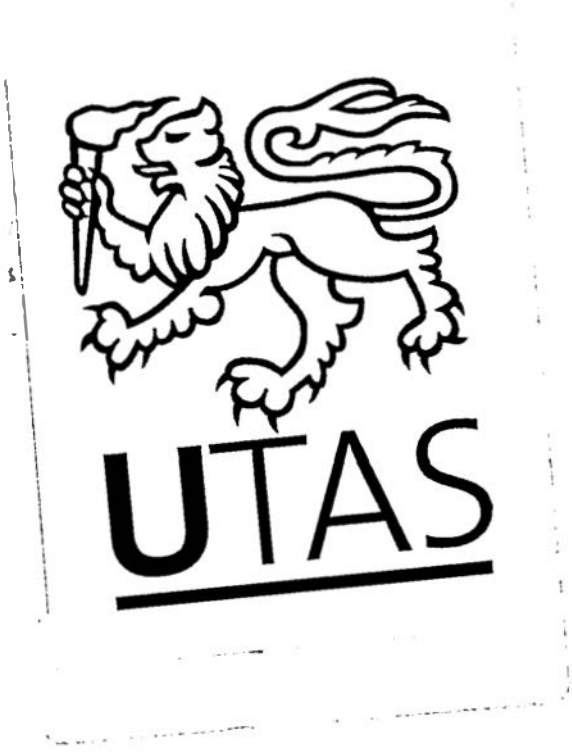


Chapter 1 - Introduction

Suburban areas are dominated by built environment composed of residential, commercial and industrial buildings, roads, paved areas and the like. The character of the suburb is determined by human activities that often result in dramatic changes from the 'natural state' of such areas; for example through extensive clearing of native vegetation, introduction of artificial materials, intrusive constructions and infrastructure. A direct effect of those changes, including alteration or degradation of the natural environment, is habitat loss and fragmentation (Webb and Foley, 1996; Jellinek *et al.*, 2004; Harper *et al.*, 2005); which can subdivide and reduce the population size of various species (Collinge, 1996), often leading to local extinctions and loss of environmental values (Webb and Foley, 1996).

1.1 Suburban areas and isolated trees as wildlife habitat

Due to an increasing scarcity of native vegetation in the suburban landscape, bush remnants, as well as isolated suburban trees, have become of great importance; not only for the city's human residents because of the aesthetic or recreational value of the remnant vegetation, but also potentially for city-dwelling wildlife by providing habitat (Hingston, 2005). Many urban areas manage to support a relatively high diversity of fauna species, because of the wide range of natural and artificial habitat types and specific conditions offered by the urban environment (Niemelä, 1999). Harper *et al.* (2008) observed that suburban areas outside bush remnants are often perceived by wildlife as continuum or another environment in which to obtain resources; hence the distinction between remnant bush patches and scattered trees outside remnants is an artificial one (McIntyre and Barrett, 1992). Resource availability within bush remnants and in surrounding suburban areas determines the habitat quality, and affects the distribution and abundance of species (Lindenmayer *et al.*, 1991; 1999; Harper *et al.*, 2008). Usually, species that commonly inhabit and thrive in the urban landscape belong to either the introduced or generalist group of species. In contrast, populations of habitat and dietary specialists, as well as migratory species, are more likely to decline in numbers or even become locally extinct (How and Dell, 2000; Tait *et al.*, 2005). This, together with the ongoing expansion of suburban areas and associated tree loss, suggests that there is an

urgent need for adequate management and conservation of native wildlife (especially specialists and migratory species) within urban environments (Garden *et al.*, 2007).

Isolated trees and tree patches may constitute only a small percentage of all trees in the landscape; however the habitat values they hold in supporting a wide range of vertebrates and invertebrates 'make them [the trees] proportionally more important than their relative abundance'(Ozolins *et al.*, 2001, 201). Isolated suburban trees are likely to significantly contribute to the persistence of native biota or biodiversity; hence cannot be ignored simply because they are a small part of the landscape (Sekercioglu *et al.*, 2007).

Although there is a lack of systematic studies revealing the extent to which wildlife use scattered suburban trees, there have been some studies conducted on isolated trees in agricultural landscapes. Due to their isolated character, paddock trees hold a certain degree of similarity with suburban trees. Indeed, Dickman (1987) noticed that the processes of fragmentation and their impact on fauna were similar between urban and agricultural landscape; hence the literature cited below refers to agricultural land.

Isolated trees, despite being no longer a part of the original woodland or forest, still have important functions as individuals (Ozolins *et al.*, 2001), as they appear to hold many conservation values in maintaining animal populations and regional biodiversity (Gibbons and Boak, 2000). According to Date *et al.* (1991), isolated trees constitute a 'connection link' or 'stepping stones' between bush remnants, in addition to existing wildlife corridors. These trees contribute to reducing the isolation of remnants by maintaining connectivity between larger patches of remnant vegetation. Many animal species use the crowns of these scattered trees to feed, as well as move through the landscape, for example in the event of periodic perturbations, such as drought, fire or disease (Gibbons and Boak, 2000). As a result, isolated trees increase viability of wildlife populations (Gibbons and Boak, 2000). For example, Law *et al.* (2000b) revealed that isolated trees on farmland in northern New South Wales provide not only a link between vegetation remnants, but also an important roosting and foraging habitat by supporting a rich vertebrate and invertebrate fauna, including a number of threatened species. Similarly, the study

conducted by Cunningham *et al.* (2008) on scattered trees on farmland in New South Wales showed their ability to provide an important habitat for many birds in decline. Tree plantings can not only contribute to supporting some bird species by offsetting the loss of remnant vegetation, but also add more taxa to the bird species richness, when the area on which tree planting occurs had low levels of remnant native vegetation cover before planting (Cunningham *et al.*, 2008).

Isolated trees are also likely to provide more flowers for nectar-dependent species, because they may grow larger and flower more intensely. Scattered trees tend to grow to a larger height and stature than contiguous bush trees due to a greater access to sunlight and often nutrients (Brereton *et al.*, 2004). Wilson and Bennett (1999) observed that there is variation in flowering intensity between different-sized trees of the same species; and a greater percentage of large trees (> 60 cm in diameter at breast height) appears to flower if compared with smaller trees. Moreover, the total canopy foliage of large trees is usually much greater than that of smaller trees (Brereton, 1996; Wilson and Bennett, 1999; Tzaros, 2002). Consequently, given the same flowering intensity, large trees will produce more flowers per tree; hence constitute a more reliable food source for nectar-dependent species (Brereton, 1996; Wilson and Bennett, 1999; Tzaros, 2002).

1.2 An urban area with remnant trees

The capital city of Tasmania, Hobart, is considered as one of the 'greenest' capital cities in Australia because of its bushland setting. Based on images taken from the Landsat satellite in 1999, remnant native cover of Greater Hobart (including the Mt Wellington Park and the Meehan Range) accounted for 26,738 ha (29.9%) (Resource Planning and Development Commission, 2003a). On a smaller scale, the city of Hobart includes extensive areas of native bushland that not only occur on the outskirts of residential development, but also within the city suburbs. According to North (2000), the estimated area of bushland within the city of Hobart is approximately 4,100 ha, which constitutes 53% of the Hobart municipality.

Mount Nelson is an example of a Hobart suburb whose most prominent feature is the surrounding native bush. Mount Nelson's leafy character, together with

the close proximity to the Hobart CBD and views on the Derwent River estuary have been attracting developers in the recent decades. The first residential subdivisions and modern development in Mount Nelson took place along the ridge top (Gulson and North, 1995) after 1945 when the government encouraged settlement of European immigrants after the World War II (Wikipedia, 2008). With time, the development has progressed down the hill face and become quite dense, especially on the lower slopes (Gulson and North, 1995). In the recent years Mount Nelson has become one of the prime residential areas in Hobart. Expanding subdivisions, as well as other factors (including increasing fuel prices) will most likely attract more people to reside in the suburb. Such changes could result in even higher development density and the compromise of existing bushland values in favour of the urban sprawl.

The bushland of Mount Nelson offers not only scenic values of a leafy setting for living and recreation, but it also contains areas of recognised regional significance by providing habitat to a diverse range of flora and fauna species. Several threatened species of animals inhabit Mount Nelson, including the Swift Parrot (*Lathamus discolor*), Masked Owl (*Tyto novaehollandiae*), and Eastern Barred Bandicoot (*Perameles gunnii*) (Hingston, 2005; Hobart City Council, 2005). This reflects an essential contribution made by Mount Nelson native vegetation to maintaining the biodiversity and ecological integrity of the area.

Swift Parrots (Plate 1) use Mount Nelson as foraging habitat during their breeding season (September –January) (Brown, 1989; Brereton, 1996). During the breeding season the birds feed primarily on the nectar of Tasmanian Blue Gum (*Eucalyptus globulus*) (Brown, 1989; Brereton, 1996; 1997), which mostly flowers between September and December (Williams and Potts, 1996). However, Black Gums (*E. ovata*) are also a significant food source for the Swift Parrot, especially in the pre-breeding season before *E. globulus* is in full flower (*E. ovata* mostly flowers from August until October) or in years when the flowering of *E. globulus* is poor (Brown, 1989; Brereton, 1996; 1997; Swift Parrot Recovery Team, 2001). It is estimated that in some breeding seasons (e.g. 2002-03; Figure 1) 5% of the estimated entire population of 2500 Swift Parrots relies on Mount Nelson *E. ovata* flowers (Hingston, 2005; 2007). An unpublished study on Swift Parrots conducted by

Andrew Hingston in Mount Nelson between the years 2002 and 2008 showed that the species foraged there every spring, feeding predominantly on *E. ovata* flowers in 2002-03, 2004-05 and 2005-06 (Figures 1 and 2). In the seasons 2003-04 and 2006-07 Swift Parrots in Mount Nelson foraged exclusively on *E. globulus*, while in 2007-08 they foraged on both *E. globulus* and *E. ovata* (Figure 2).

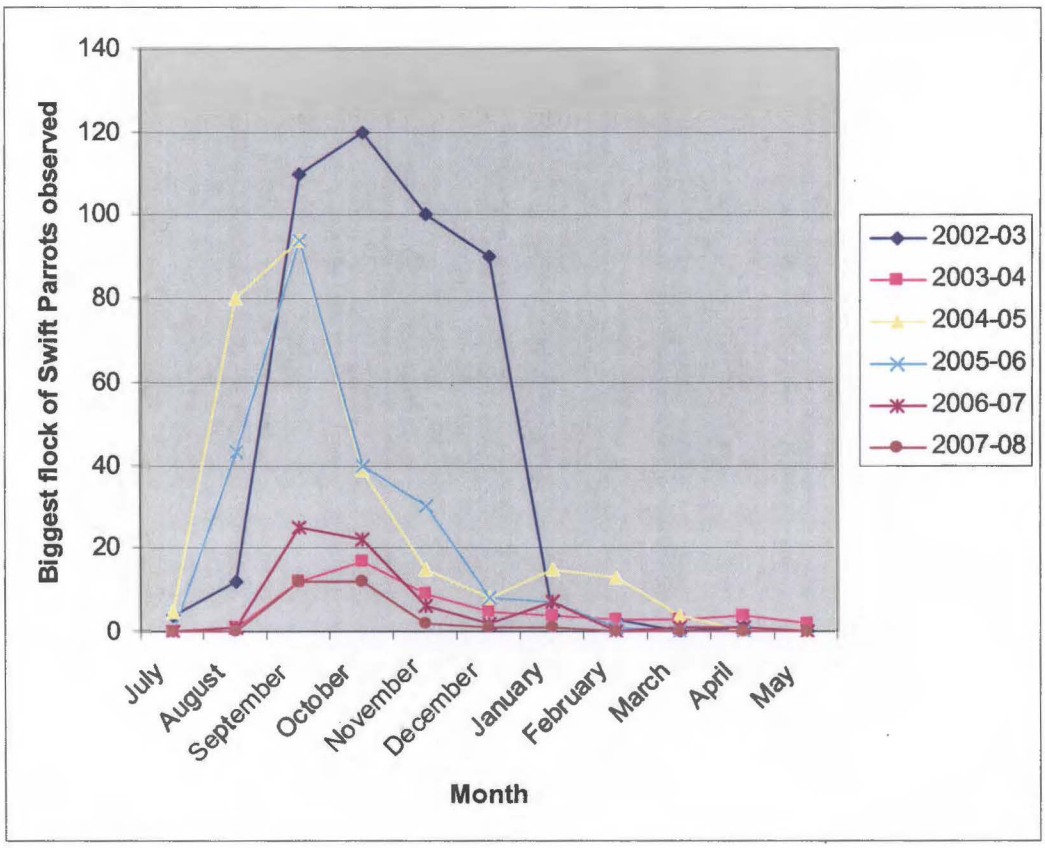


Figure 1. Biggest flock of Swift Parrots observed in Mount Nelson in each month from July to May in six successive seasons (A. Hingston, unpublished data).

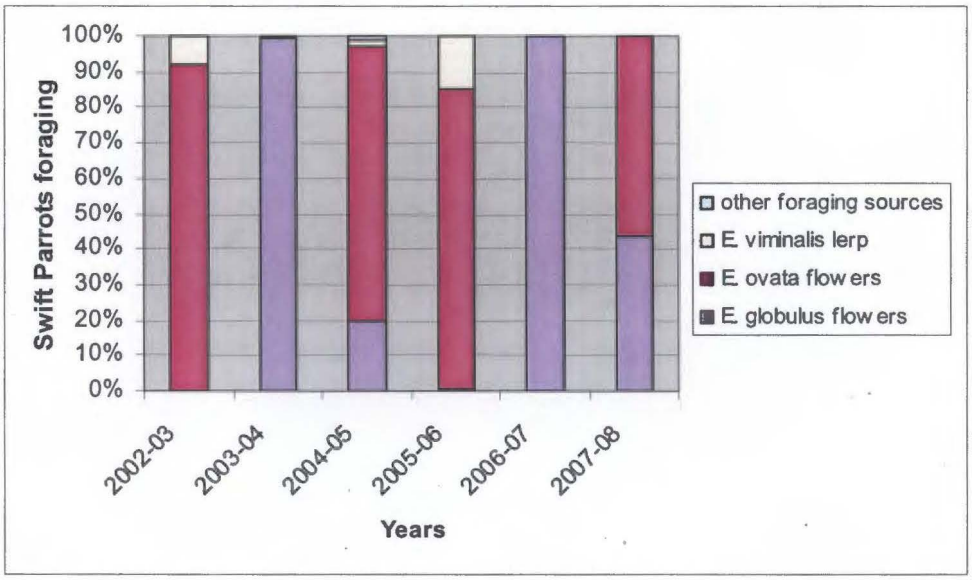


Figure 2. Foraging records of Swift Parrots in Mount Nelson in six successive seasons (A. Hingston, unpublished data).

Maintenance of the Swift Parrot habitat is important because the species is listed as endangered both in the State of Tasmania and nationally (Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*; Schedule 3 of the Tasmanian *Threatened Species Protection Act 1995)*. The total population of the species is estimated to be fewer than 2500 mature individuals (Garnett and Crowley, 2000; Swift Parrot Recovery Team, 2001; Saunders *et al.*, 2007; Saunders and Heinsohn, 2008), which makes the Swift Parrot Australia's third rarest parrot species (Tzaros, 2002). The major threat to the species is loss of habitat due to timber harvesting, clearance for agriculture and urban development (Brereton, 1996). Reproductive success of the Swift Parrot strongly depends on the extent and intensity of flowering of *E. globulus* (Brown, 1989; Brereton, 1996; 1997; Gartrell, 2001; Swift Parrot Recovery Team, 2001; Tzaros, 2002) and, to a lesser extent, *E. ovata* (Brereton, 1996; Hingston, 2007). It has been observed that in the years of poor *E. globulus* flowering, the breeding success of the Swift Parrot is lower than in the years of heavy flowering (Brereton, 1996; Tzaros, 2002; Hingston, 2007). While only 18% of the Swift Parrot's foraging habitat (*E. globulus* dry forest) within the breeding range is reserved, 82% occurs on private land (Swift Parrot Recovery Team, 2001). Similar information for *E. ovata* forests is not available. However, only

2% of nesting habitat is within reserves, with the majority of nests found on private land (Brereton, 1997).

In search for food Swift Parrots are capable of using all sizes of eucalypt patches (even in a highly-fragmented landscape), including small patches of less than one hectare and isolated suburban trees in gardens and parkland (Brereton, 1996; 1997; Mallick *et al.*, 2004), sometimes travelling large distances to utilise flowering patches (Bryant and Jackson,1999). Swift Parrots exhibit a preference for larger trees (Kennedy and Overs, 2001; Tzaros, 2002; Brereton *et al.*, 2004; Kennedy and Tzaros, 2005) and trees of more than 30 years old (Brereton, 1996), due to their reliable nectar production (Traill, 1993; Wilson and Bennett, 1999; Law *et al.*, 2000b; Kennedy and Tzaros, 2005).

Swift Parrots also utilise nest hollows of a range of eucalypt species, usually *E. obliqua*, *E. pulchella* and *E. globulus* trees located in shrubby or grassy dry forests on ridge tops and hillsides, away from immediate feeding locations (Brown, 1989; Brereton, 1996; 1997). Brown (1989) observed that the Swift Parrot's nests were particularly common in areas moderately or severely affected by fire.

Plate 1. Swift Parrot feeding on nectar from a *Eucalyptus globulus* flower (Photograph: A. Hingston).

1.3 Study aims

The aim of the project was to investigate the relative value of large eucalypt trees in the bush and suburban areas of Mount Nelson, Tasmania, as foraging habitat for Swift Parrots. *Eucalyptus globulus* and *E. ovata* trees were selected for this study because they constitute a critical food source for the Swift Parrot (Brown, 1989; Brereton, 1996; 1997), and Mount Nelson was chosen as the research area because it is one of the feeding grounds for the species (Gulson and North, 1995; Hingston, 2007; Figure 2). The study also aimed to investigate the recent and current trends of tree removal from private properties in Mount Nelson, as well as future plans for tree felling, in order to determine whether the forage sources for the Swift Parrot are declining within the suburb.

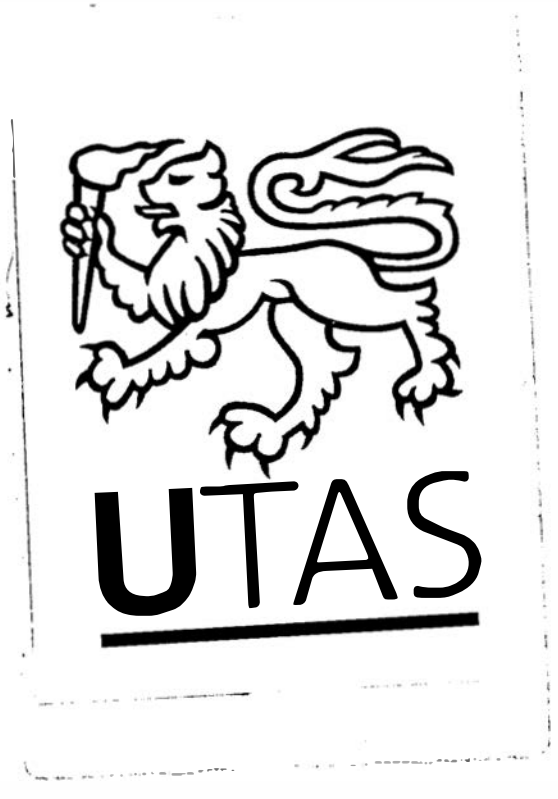
The following specific research questions were addressed:

1) Is there a difference in flowering intensity between suburban eucalypts (*E. ovata* and *E. globulus*) and their bush and edge counterparts?
2) Is flowering intensity affected by certain structural tree variables (tree height, tree basal area, canopy density, tree dieback and the percentage of branches in the canopy that were dead) or environmental variables of the tree's location (Moisture Index based on aspect, ground slope, topography, fire history)?
3) How many large *E. globulus* and *E. ovata* trees have been removed or are going to be removed from private properties in Mount Nelson, and what are the most common reasons for tree removal?

1.4 Thesis structure

Chapter 1 has introduced some literature behind the scope of the study, as well as the main aims of this project. Chapter 2 describes the study area, tree selection prerequisites, field work procedures (including the conducted survey) and various data analyses used during the study. Chapter 3 reveals the results. First, it encompasses the effects of the tree context (suburban, edge and bush) on the flowering variables of capsule load and opercula number. Second, various structural and environmental variables are examined in relation to the context, capsule load

and opercula number, in order to investigate their effect on flowering. Chapter 3 also presents the results of the anonymous questionnaire conducted among Mount Nelson residents, showing the trends of the past and future tree felling within the suburb, as well as the current numbers of large *E. globulus* and *E. ovata* on private properties. A general discussion of the results and their implications follow in Chapter 4. Chapter 5 constitutes the overall conclusion of the study.



Chapter 2 - Methods

2.1 Study area

The study area selected for this project encompassed a large part of Mount Nelson, located on the western shore of the Derwent River estuary, south-east Tasmania (Figure 3). The name Mount Nelson indicates both a suburb of Hobart and a landform, which constitutes a foothill of the Wellington Range (Gulson and North, 1995). The study area covers most of the suburban areas in Mount Nelson, as well as large areas of bushland, such as Bicentennial Park, Hobart College bush and University Reserve (Figure 4). Note should be taken that both Porter Hill adjacent to Mount Nelson (including Cartwright Reserve) and Truganini Conservation Area have not been included in the study area due to time limitations of this project.

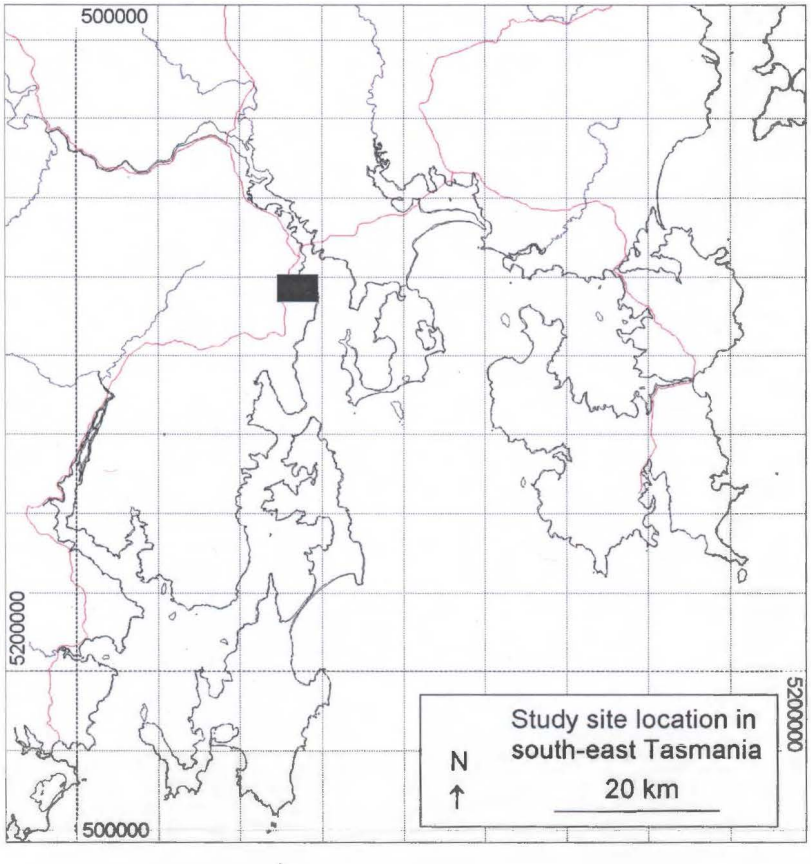


Figure 3. Study site location in south-east Tasmania.

The mean monthly minimum and maximum temperature recorded at the Hobart Regional Forecasting Centre in Battery Point (no direct data available for Mount Nelson) ranges from 5°C to 12°C in July, to between 11°C and 22°C in January. The mean yearly rainfall at the Mount Nelson Signal Station (335 m a.s.l.) is 666 mm (Bureau of Meteorology, unpublished data; in Hickie, 1998, 14), which is relatively dry for the metropolitan area (Hobart City Council, 1997). Westerly winds are most prominent in Mount Nelson; however localised wind changes due to the topography of Mount Nelson are common. In summer dry north-westerly winds increase the danger of fires in the area (Hickie, 1998).

Mount Nelson is predominantly underlain by Jurassic dolerite and Permian mudstone (Hobart City Council, 1997), which affect the type of soil. They range from shallow grey-brown podzolics on dolerite bedrock on the ridge top of Mount Nelson, through brown soils on dolerite on the steeper slopes, to deeper black earths on dolerite in the lower parts of the northerly slopes, and podzolic soils formed on mudstone on the western flank below Hobart College (Spanswick and Kidd, 2000).

2.2 Tree selection

Only large trees were included in the study because the Swift Parrot has shown a preference for larger eucalypts (Kennedy and Overs, 2001; Tzaros, 2002; Brereton *et al.*, 2004; Kennedy and Tzaros, 2005). Since their flowering intensity is greater than that of smaller trees (Wilson and Bennett, 1999), larger trees constitute a more reliable food source for nectarivorous birds, including the Swift Parrot (Brereton, 1996; Wilson and Bennett, 1999; Tzaros, 2002). Large trees were defined here as having a Diameter at Breast Height Over Bark (DBHOB) of at least 60 cm, measured at a standard height of 129.54 cm from the ground (Kennedy and Overs, 2001). Data from a sample of 261 randomly selected large trees was collected within three tree contexts, including 84 suburban trees, 152 bush trees and 25 edge trees (Figure 4).

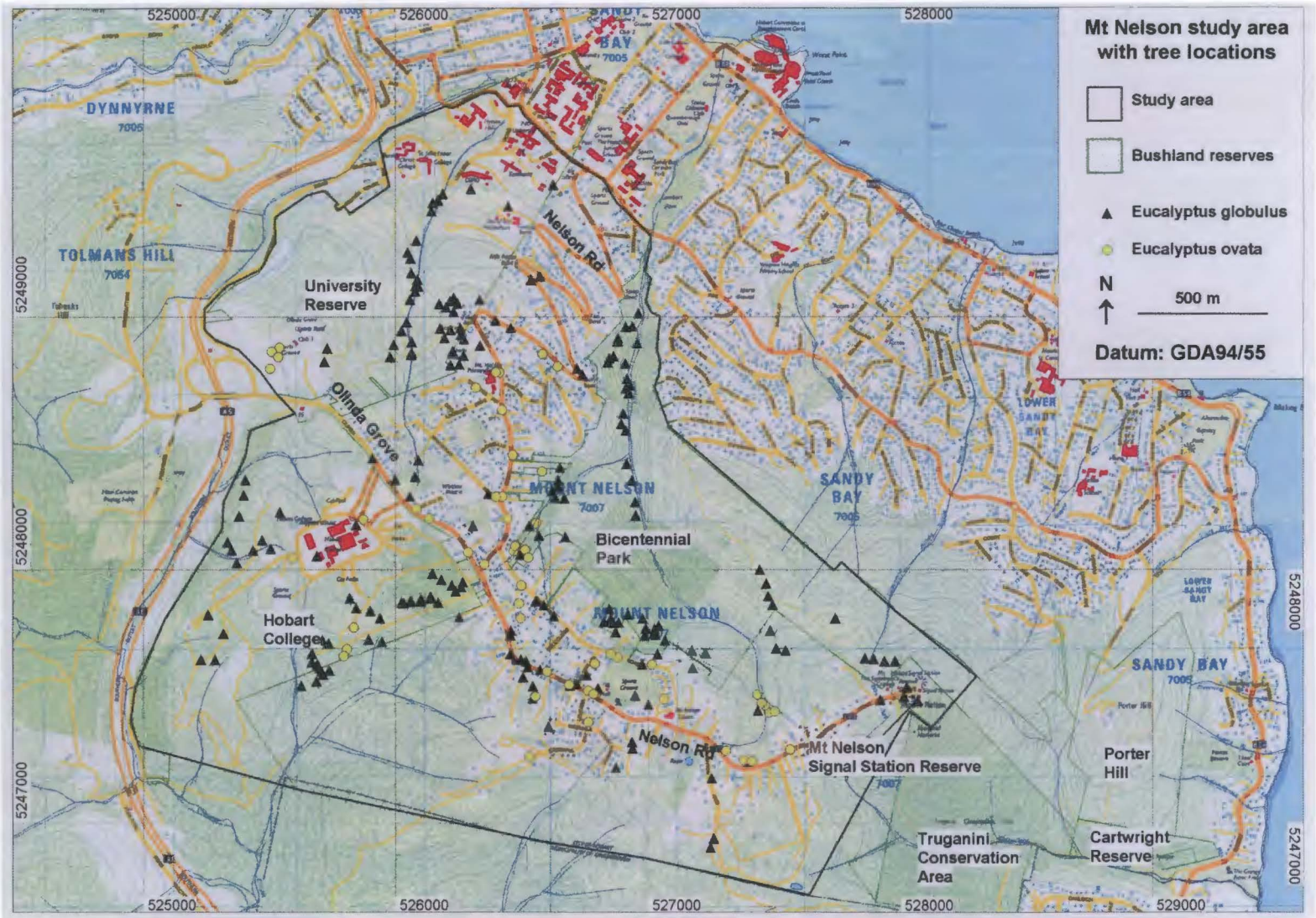


Figure 4. Mount Nelson study area with marked locations of measured *E. globulus* and *E. ovata*.

Suburban trees (Plate 2) were regarded as trees in close proximity to residential (dwellings) and commercial buildings/facilities (i.e. shops, schools, restaurants, public toilets or sport grounds), or infrastructure (i.e. roads, concrete and gravel pathways, or driveways). The vegetation within 20 m of a suburban tree has been modified by urban human activity (i.e. lawns, gardens, pathways, roads, buildings). Such trees, despite their origin (whether they have been planted or constitute remnants of the native bush), can be seen either as small/medium-sized bushy patches or scattered, isolated trees.

Edge trees (Plate 3) were considered as those trees found in the zone between suburban and bush areas (up to 39 m from the existing suburban development); including fire breaks between the suburban context and bush, as well as residential blocks that resemble bush in their conditions and general setting.

Bush trees (Plate 4), on the other hand, were found within a bush remnant and at least 40 m from the existing suburban development. Bush remnants are defined here as publicly or privately owned land 'on which there is vegetation [that] is either a remainder of the natural vegetation of the land or, if altered, is still representative of the structure and floristics of the natural vegetation' (Webb and Foley, 1996, 3). As well as larger areas of bush in Mount Nelson, there are also several smaller bush-like patches tucked in-between residential areas. Despite their small size and close proximity to the suburban areas, they still remain in a relatively natural state and are often connected to a larger area of bushland, which enhances their natural character.

Dry sclerophyll forests and woodlands, as well as wet sclerophyll forests, are the prevailing vegetation types of the Mount Nelson bush (Hingston, 2005). The characteristics of the understorey (grassy, sedgy, heathy or shrubby) determine the classification of the eucalypt-dominated communities (Duncan, 1999). The foliage cover of dry sclerophyll forests and woodlands is dominated by various eucalypt trees and occasionally by *Allocasuarina verticillata*; while the multi-layered understorey is dominated by xeromorphic species. The canopy of wet sclerophyll forests is also dominated by eucalypt species; while the understorey (often dense) consists of tall shrubs and small trees (Kirkpatrick and Gilfedder, 1999). The species from subgenus *Monocalyptus* series *Piperitae* (the peppermints, including

E. pulchella and *E. tenuiramis*) usually dominate the dry sclerophyll forests; while subgenus *Monocalyptus* series *Obliquae* (the ashes, including *E. obliqua*) predominantly occurs in the wet sclerophyll forests. Trees from subgenus *Symphyomyrtus* series *Ovatae* and *Viminales* (the gums, including *E. globulus*, *E. ovata* and *E. viminalis*) are found either as subdominants or dominate in specific niches (Reid and Potts, 1999).

The selected study area includes three large bushland areas: Bicentennial Park, Hobart College bush and University Reserve (Figure 4).

- Bicentennial Park is dominated by the following forest communities: *E. pulchella/E. globulus/E. viminalis* grassy and shrubby dry sclerophyll forest (Epa, Epb), and *E. globulus* wet sclerophyll forest (GLOB0100, GLOB1) in the Lambert Gully along the Lambert Rivulet.
- The forest communities of Hobart College bush include *E. pulchella/E. globulus/ E. viminalis* grassy and shrubby dry sclerophyll forest (Epa, Epb), *E. globulus* wet sclerophyll forest (GLOB1), *E. obliqua* wet sclerophyll forest (OB010) and a patch of *E. tenuiramis* dry sclerophyll forest (Eth).
- University Reserve is dominated by *E. viminalis* grassy woodland (Evam), *E. pulchella/E. globulus/E. viminalis* grassy and shrubby dry sclerophyll forest (Epa, Epb), and *E. globulus* wet sclerophyll forest (GLOB0100) in the gully along the Rifle Range Creek (Gulson and North, 1995).

Within Mount Nelson bushland areas, trees were selected from the following two major forest communities: 1) *E. pulchella/E. globulus/E. viminalis* grassy/shrubby dry sclerophyll forest dominated by *E. globulus*, *E. pulchella*, *E. viminalis*, *E. ovata* and *E. obliqua*; and 2) *E. globulus* wet sclerophyll forest with dominant *E. globulus* (Gulson and North, 1995). The underlying geological rock formation for all the sampled trees was Jurassic dolerite.

Plate 2. An example of trees in a suburban context. Left photo: *E. ovata*, Nelson Road; Right photo: *E. ovata*, Brinsmead Road, Mount Nelson, March 2008 (Photograph: Author).

Plate 3. An example of a tree in an edge context. The fire break between University Reserve and residential areas, Mount Nelson, March 2008 (Photograph: Author).

Plate 4. An example of trees in a bush context. Hobart College bush, Mount Nelson, March 2008 (Photograph: Author).

2.3 Field work procedure

The species (*E. globulus* or *E. ovata*) and tree context were recorded, and eastings and northings of each tree taken using a Global Positioning System (GPS).

2.3.1 Flowering

The field work commenced in early March and finished mid-April 2008, a period in which most Swift Parrots had left south-east Tasmania (Figure 1). Hence, it was not possible to obtain new bird sightings during the course of the study and the thesis only focuses on the already known habitat of the birds. Moreover, the flowering of *E. globulus* and *E. ovata* occurs outside the months in which the field work was conducted (Brown, 1989). As a result of that, the measurements of tree flowering, rather than being based on direct observations of the actual flowers, focused both on the seed capsule abundance and counts of opercula that have fallen from flowers. Opercula here relate only to *E. globulus* and represent caps (> 1.5 cm in diameter) that cover the reproductive organs before anthesis (Florence, 1996) (Plate 5). It is known that flowering patterns of eucalypts (including periodicity and

intensity) vary markedly between years (Jacobs, 1955; Ashton, 1975; Brooker and Kleinig, 1990; Pook *et al.*, 1997; Reid and Potts, 1999; Law *et al.*, 2000a). Usually for *E. globulus*, a year of intense flowering is followed by poor flowering and vice versa (Brown, 1989; Brereton, 1996), which is likely to be determined by particular seasonal conditions that affect bud formation and development (Brereton, 1996; House, 1997). Therefore, several years' data are needed to understand the general flowering trends. The capsules of most Tasmanian eucalypt species are usually retained in the canopy for several years (Reid and Potts, 1999). Hence, capsule abundance (load) indicates the abundance of flowers from the past few flowering seasons (A. Hingston, pers. comm.); whereas the number of opercula provides a good approximation of the abundance of flowers that reached anthesis in the recent flowering event (providing only fresh opercula are counted; Plate 5). In fact, the number for opercula is an equivalent to the number of buds that flowered; hence can be readily identified with a bud crop from a particular flowering season (Pook *et al.*, 1997).

Capsule load for both *E. globulus* and *E. ovata* was estimated visually from the ground by using a pair of binoculars and expressed in per cent of the maximum density of capsules observed for a tree of each species during the study. Note should be taken that the size of *E. globulus* woody capsules (Plate 6) is rather large and ranges from 1.5 to 2.5 cm in diameter (Boden, 2006; Wiltshire and Potts, 2007); whereas *E. ovata* capsules (Plate 7) are much smaller with a diameter of approximately 0.8 cm (Walsh and Entwisle, 1996). Capsules both in the tree and on the ground (including floral receptacles that did not develop into mature capsules) were taken into consideration, because of possible variation in capsule retention (Florence, 1964; Hingston, 2002). The observed number of capsules was then incorporated into one of the following categories: 0 = no capsules; 1 = < 10%; 2 = 10-40%; 3 = 40-70%; 4 = > 70%. In addition, for all the *E. globulus* trees an operculum count was performed in three quadrats of 1 m x 1 m randomly placed underneath each tree. Only fresh opercula (from the recent flowering event) were counted and differentiated from older opercula by the brighter, yellowish colour of the former (Plate 5). Based on this count, a mean number of opercula (per square metre) was calculated.

Plate 5. ***Eucalyptus globulus*** **fresh opercula, March 2008 (Photograph: Author).**

Plate 6. ***Eucalyptus globulus*** **capsules, March 2008 (Photograph: Author).**

Plate 7. *Eucalyptus ovata* capsules, March 2008 (Photograph: Author).

2.3.2 Structural and environmental tree variables

I investigated the relationships of flowering and context with several structural and environmental variables (tree height, tree basal area, canopy density, tree dieback, the percentage of branches in the canopy that were dead, ground slope, topography, fire damage and Moisture Index based on aspect), primarily to guard against the possibility of any relationships between flowering and context being the result of confounding tree structural and environmental variables; and to explore which of the tree variables contributed to any relationships between flowering and context. Firstly, I examined whether there was a relationship between the tree variables and context for each eucalypt species. Secondly, I investigated whether these variables were related to flowering of each eucalypt species. I then looked at the relationship between fire damage, and canopy density, tree dieback and the percentage of branches in the canopy that were dead, in order to further examine the implications of fire.

Tree height was measured in metres using an optical reading clinometer. Circumference of each tree (measured in centimetres using a diameter tape) was converted into a Tree Basal Area (TBA), which is the cross-sectional area over the

bark at breast height measured in square metres (Farm Forest Line, n.d.). The following equations were used to calculate TBA:

$$\text{Diameter} = \text{Circumference} \div 3.142$$

$$\text{Radius} = \text{Diameter} \div 2$$

$$\text{TBA} = (\text{Radius})^2 \times 3.142$$

For trees with multiple stems, the tree basal areas of each stem were added together. For trees found on a slope, the breast height was measured on the downhill side.

Canopy density was estimated visually and recorded in per cent (Walker and Hopkins, 1990). The percentage of canopy density was calculated by subtracting the percentage of light coming through the canopy from a theoretical hundred per cent of canopy cover.

Tree dieback was estimated visually and described as one of the following: 1 = healthy; 2 = generally healthy with some dieback; 3 = showing clear signs of senescence; 4 = advanced senescence.

The overall percentage of branches in the canopy that were dead was also identified visually and classified as one of the following categories: 1 = 0-5% (Plate 8); 2 = 5-20%; 3 = 20-50%; 4 = > 50% (Plate 9). The two last classifications (tree dieback and the percentage of branches that were dead) were based on classes proposed by M. Webb (pers. comm.).

Aspect for locations with some slope was measured in degrees in the field and later classified into five classes of Moisture Index (MI) (1 = north-west; 2 = west and north; 3 = south-west and north-east; 4 = south and east; 5 = south-east), following the aspect classes used by Jones (2004) (Figure 5). These classes were used because it is known that in the southern hemisphere the northern aspects receive more solar radiation per unit area than do southern aspects (Jacobs, 1955; Pook and Moore, 1966; Kirkpatrick and Nunez, 1980; Florence, 1996; Brereton, 1997), and the moisture is least on the north-west facing slopes and most on the south-east facing slopes (Kirkpatrick and Nunez, 1980) because of the prevailing dry north-westerly winds (Hickie, 1998).

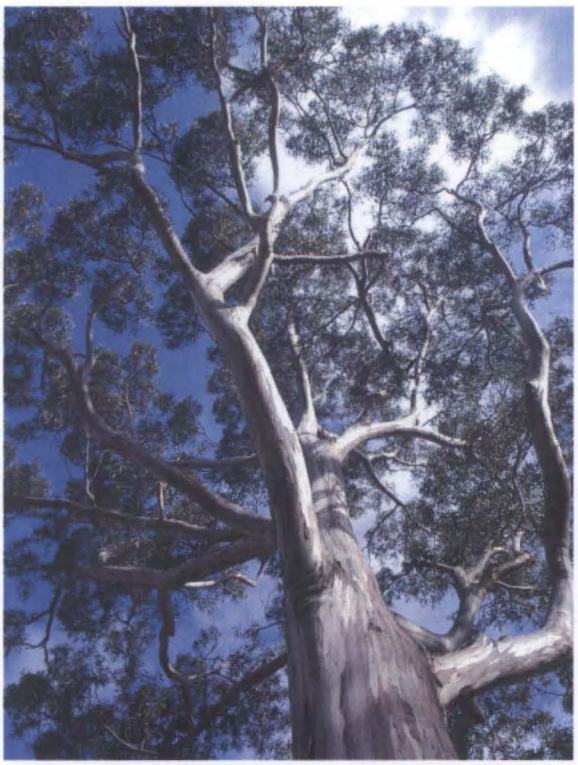


Plate 8. *Eucalyptus globulus* with 0-5% of branches in the canopy dead, Mount Nelson Oval, Mount Nelson, March 2008 (Photograph: Author).

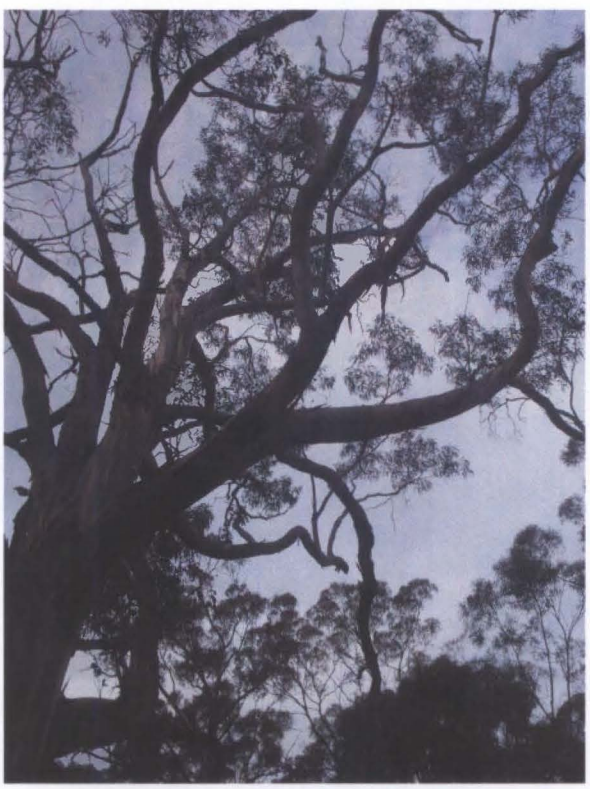


Plate 9. *Eucalyptus globulus* with more than 50% of branches in the canopy dead, Bicentennial Park, Mount Nelson, March 2008 (Photograph: Author).

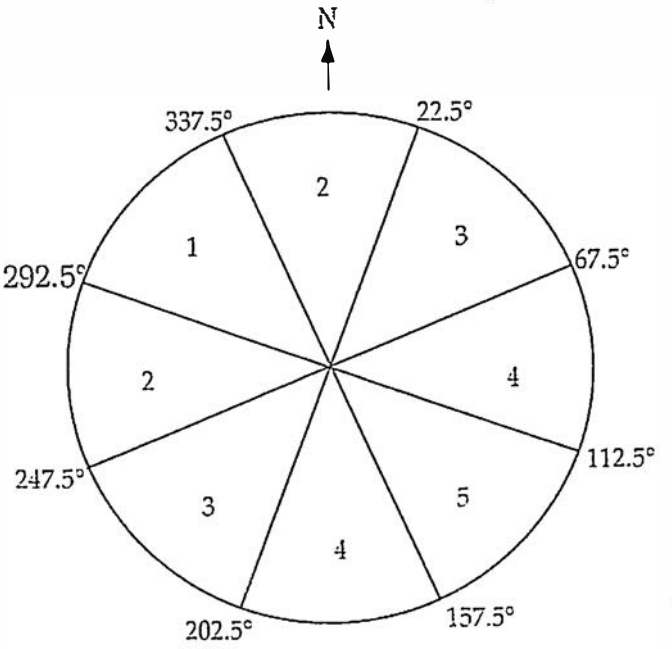


Figure 5. Moisture Indices based on aspect (Jones, 2004).

The ground slope at the tree location was measured in degrees with a clinometer. The slope on flat terrain, such as a ridge top or bottom of a gully, was recorded as zero. For trees found on a slope with an angle upslope different from the one downslope, a mean of both figures was recorded.

Topography was categorised as 1 = ridge; 2 = upper slope; 3 = mid slope; 4 = lower slope; and 5 = gully (drainage line). For the purpose of this study, a ridge was considered to be the narrow stretch of land from the Signal Station to the beginning of Proctors Road (mainly following Nelson Road and Olinda Grove, with an exception where the ridge climbs up towards the top of Broughton Avenue and descends towards Weemala Court). Based on this ridge location, other topography classes were then estimated.

Fire damage was recorded using the following classification proposed by Koch (2007): 0 = no evidence of fire (Plate 10); 1 = bark damage (Plate 11); 2 = wood exposed and damaged by fire (Plate 12); 3 = severe fire damage such as a bridge or large hollow in the base of the tree (Plate 13).

Plate 10. ***Eucalyptus globulus*** **with no fire damage, Bicentennial Park, Mount Nelson, March 2008 (Photograph: Author).**

Plate 11. ***Eucalyptus globulus*** **with bark damage, Hobart College bush, Mount Nelson, March 2008 (Photograph: Author).**

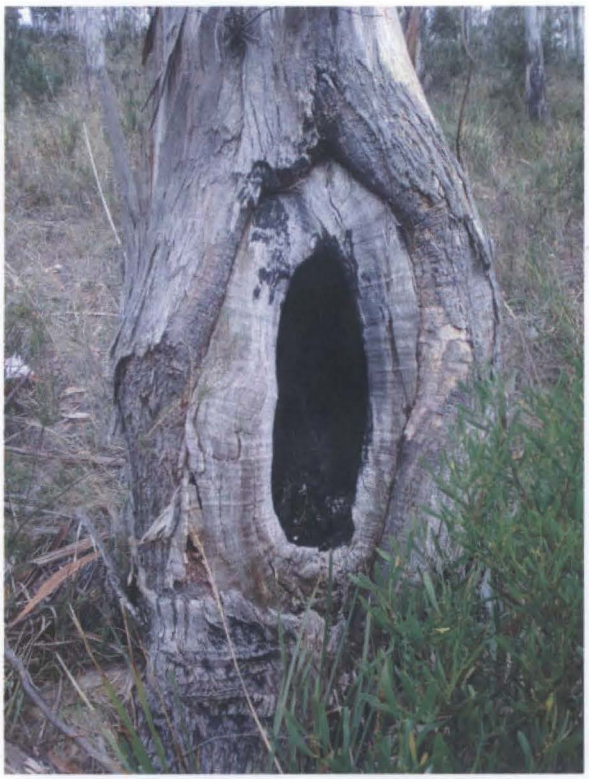


Plate 12. ***Eucalyptus globulus*** **with wood exposed and damaged by fire, Hobart College bush, Mount Nelson, March 2008 (Photograph: Author).**

Plate 13. ***Eucalyptus globulus*** **with severe fire damage (large hollow in the tree base), Hobart College bush, Mount Nelson, March 2008 (Photograph: Author).**

2.4 Questionnaire

In addition to the above research, an anonymous survey was conducted among Mount Nelson residents in order to obtain information regarding large eucalypt trees on private properties (Appendix 1). The main purpose of this survey was to examine whether people have had large trees felled or intend to have large trees felled on their property. This information was further needed to establish how many large trees have been felled in recent years and the extent to which remaining trees are at risk of removal. Residents of Mount Nelson, selected from the study area marked in Figure 4 (excluding those living in flats), were surveyed via a hand delivered letter with a self-addressed envelope attached, which was placed in letterboxes. In total, 830 letters (including one survey form) were dispatched. An ethics clearance has been obtained for this part of the study (Ethics Reference Number H10037).

Questions in the survey were designed to elicit the following information: the ownership status, presence of large eucalypts on the property, removal of large eucalypts in the past five to ten years, future eucalypt removal and reasons for that removal (Appendix 1).

2.5 Data analysis

Several statistical methods were employed in this study, including Kruskal-Wallis test, linear regression and Pearson Chi-Square test. Whenever statistically significant differences were found by the Kruskal-Wallis test, subsequent post hoc pair-wise analyses were conducted using Mann-Whitney U-tests with Bonferroni adjustment, which (the latter) modified the value of α (0.05). Minitab 14 for Windows (statistical software package) was used for all analyses, except for Pearson Chi-Square test that was performed manually. Each of the two eucalypt species was analysed separately. The methods of data analysis are briefly outlined below, together with the data they apply to.

2.5.1 Kruskal-Wallis test

Kruskal-Wallis test is a non-parametric test based on the analysis of ranked

data and tests equality of medians among groups. It does not assume a specified parametric distribution (i.e. normality) (Gotelli and Ellison, 2004). Instead, this technique works for a range of different distributions (Sokal and Rohlf, 1995). If P-value (α) is 0.05 or less, the null hypothesis, which assumes that mean ranks of all groups do not substantially differ, is rejected (Lowry, n.d.). Non-parametric instead of parametric methods were used in this study because the assumptions of analysis of variance, such as homogenous variances and normal distribution, were not met.
A post hoc pair-wise Mann-Whitney U-test with Bonferroni adjustment (calculating an adjusted probability based on the number of comparisons made) was employed to test for differences between sampled groups.

Kruskal-Wallis test was used to examine the relationships between context, eucalypt flowering, and tree structural and environmental variables. In detail, the test was used to investigate the significance of differences among the three tree contexts (suburban, bush and edge) in the following: flowering variables (capsule load and *E. globulus* opercula number), structural variables (tree height, tree basal area, canopy density, tree dieback and the percentage of branches in the canopy that were dead) and environmental variables (Moisture Index based on aspect, ground slope, topography and fire). Moreover, the Kruskal-Wallis test assisted in examining whether capsule load categories of *E. globulus* and *E. ovata* were related to any of the above mentioned structural and environmental variables. Also, by using this non-parametric method, *E. globulus* opercula were compared against canopy density, tree dieback, the percentage of branches in the canopy that were dead, Moisture Index based on aspect, topography and fire damage. The relationships between fire, and canopy density, tree dieback and the percentage of branches that were dead for both *E. globulus* and *E. ovata* were also examined using the Kruskal-Wallis test. When categorical data were analysed, the numbers denoting the various categories were used as ranks in the analysis (Section 2.3).

2.5.2 Linear regression

Linear regression is used to estimate the association between two variables, in which the response (dependent) variable is expressed in terms of a linear function of one or more explanatory (independent) variables (Crawley, 1993; Sokal and Rohlf,

1995; Gotelli and Ellison, 2004). In other words, the purpose of linear regression is to predict the value of the dependent variable based upon the values of one or more independent variables. The dependent variable must be measured on a continuous measurement scale and the independent variable(s) can be measured on either a categorical or continuous scale (Statistically Significant Consulting, LLC, 2008).

In this study, regression was applied to determine the relationship between the mean *E. globulus* opercula number and each of the continuous variables of tree height, tree basal area and ground slope. Regression here was used to explore relationships between variables and answer the question of whether changes in one variable (tree height, tree basal area or ground slope) were associated with variation in the other variable (opercula number).

2.5.3 Pearson Chi-Square test

Pearson Chi-Square test compares observed data with the data that is expected to be obtained according to a specific hypothesis. It is used to examine the independence of two random categorical variables (Gotelli and Ellison, 2004). If the Chi-Square P-value is 0.05 or less, the null hypothesis, assuming that frequency distribution of certain events observed is consistent with an expected distribution, is rejected (Statistically Significant Consulting, LLC, 2008).

In this study, a Pearson Chi-Square test was used to test whether the eucalypt species (*E. globulus* and *E. ovata*) in Mount Nelson are removed at the frequency expected by their abundance, or whether there is a preference for removal of one species over the other.

Chapter 3 - Results

3.1 Trees sampled

I sampled a total of 261 large trees, including 207 *E. globulus* and 54 *E. ovata* (Table 1; Figure 4). The distribution of both eucalypt species between suburban and bush contexts in Mount Nelson shows a scarcity of large *E. ovata* trees within the study area. Particular difficulty in finding large (> 60 cm DBHOB) *E. ovata* was observed in the bush and edge contexts (Table 1).

Table 1. The total number of measured trees (*E. globulus* and *E. ovata*).

Tree species	Tree context			Total
	Suburban	Edge	Bush	
E. globulus	47	19	141	**207**
E. ovata	37	6	11	**54**
Total	**84**	**25**	**152**	**261**

3.2 Flowering

There was a significant difference among the three contexts (suburban, edge and bush) in the mean number of *E. globulus* opercula collected from three quadrats (1 m x 1 m) ($H_2 = 66.03$, $P < 0.001$; Figure 6). Post hoc pair-wise tests showed that there were significant differences in opercula numbers between suburban and bush trees ($P < 0.0001$), suburban and edge ($P = 0.012$), and edge and bush trees ($P = 0.0013$; $\alpha = 0.017$ after Bonferroni adjustment). Suburban *E. globulus* had many more opercula than their edge or bush counterparts (Figure 6).

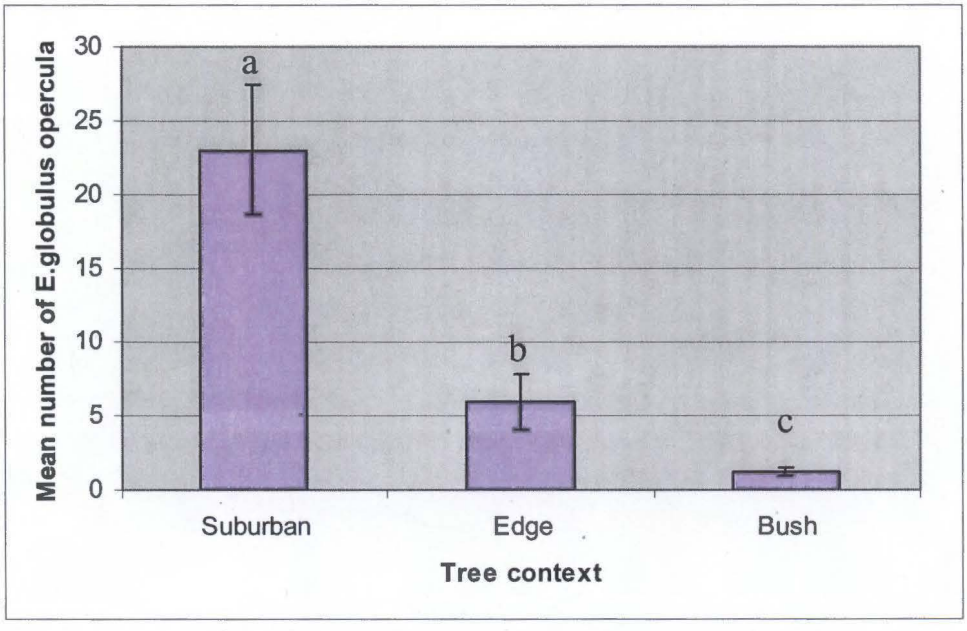


Figure 6. Comparison of *E. globulus* mean opercula number per square metre in the three tree contexts. Standard errors shown. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

There was also a highly significant difference in the capsule load among the three contexts for *E. globulus* ($H_2 = 19.34$, $P < 0.001$; Figure 7). Post hoc pair-wise tests showed a significant difference in capsule load between suburban and bush contexts ($P < 0.0001$); whereby suburban trees had more capsules (Figure 7). However, there was no significant difference between suburban and edge trees ($P = 0.32$), or edge and bush trees ($P = 0.042$; $\alpha = 0.017$ after Bonferroni adjustment). Figure 7 shows that the overall percentage of *E. globulus* trees that were observed to

have no capsules or only a small capsule load (< 40%) was greatest in the bush (82%), lower in the edge (63%) and lowest in the suburban context (51%). A noticeably large proportion of trees with capsule load of < 10% was observed in the bush (50%). Trees with a capsule load of > 40% were more abundant in the suburban context (49%) than they were in the bush (18%) or edge (37%) contexts. This was particularly pronounced for trees with a capsule load of > 70%.

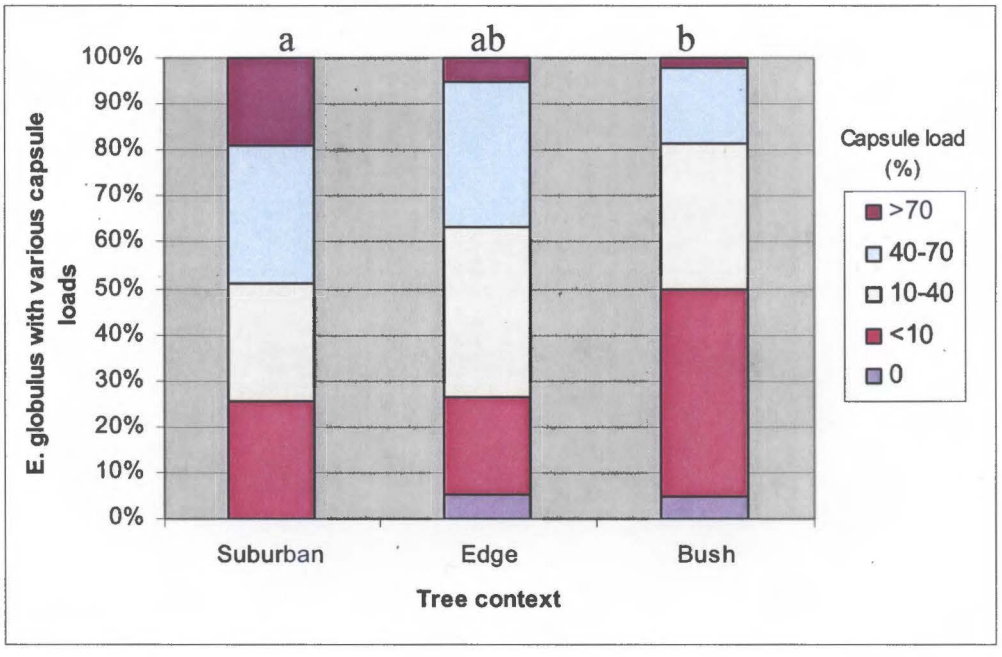


Figure 7. Comparison of *E. globulus* capsule loads in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters (α = 0.017, following Bonferroni adjustment).

Similarly to *E. globulus*, the difference in *E. ovata* capsule load among the three contexts was highly significant ($H_2 = 22.02$, $P < 0.001$; Figure 8). Post hoc pair-wise tests revealed highly significant differences in capsule load between suburban and bush trees ($P < 0.0001$), and suburban and edge trees ($P = 0.0081$); whereby suburban trees had more capsules (Figure 8). No pronounced difference, however, was recorded between edge and bush trees ($P = 0.11$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 8). The proportion of *E. ovata* trees that had no or a small amount of capsules (< 40%) was greater in the bush (73%) than it was in the edge context (33%) or in the suburbs (11%). Trees with < 10% capsule load occurred only in the bush context. Eighty-nine percent of suburban trees had capsule loads of > 40%. The

corresponding figures were less for edge (67%) and bush (27%) contexts, in both of which trees with a capsule load of > 70% were absent (Figure 8).

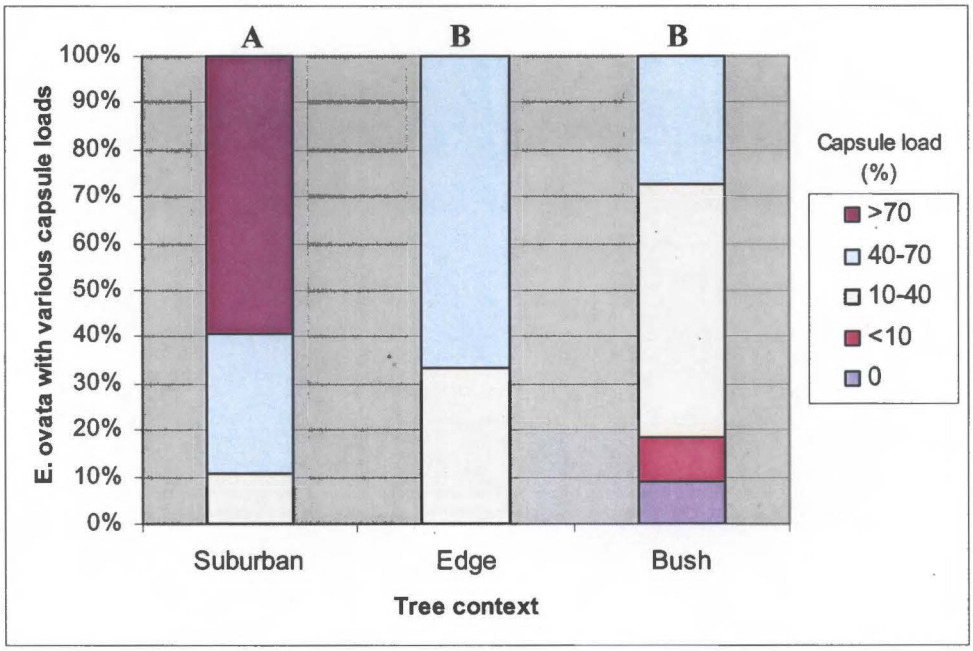


Figure 8. Comparison of *E. ovata* capsule loads in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

3.3 Structural tree variables

3.3.1 Tree height

There was a significant statistical difference in *E. globulus* height among the three contexts ($H_2 = 15.08$, $P = 0.001$; Figure 9). Post hoc pair-wise tests showed significant differences in height between suburban and bush trees ($P = 0.0051$), as well as edge and bush trees ($P = 0.0019$); whereby bush *E. globulus* were found to be taller than suburban and edge trees (Figure 9). No significant difference was found between the heights of suburban and edge *E. globulus* ($P = 0.22$; $\alpha = 0.017$ after Bonferroni adjustment). There was no statistically significant difference in the height of *E. ovata* trees among the three contexts ($H_2 = 3.03$, $P = 0.22$; Figure 9).

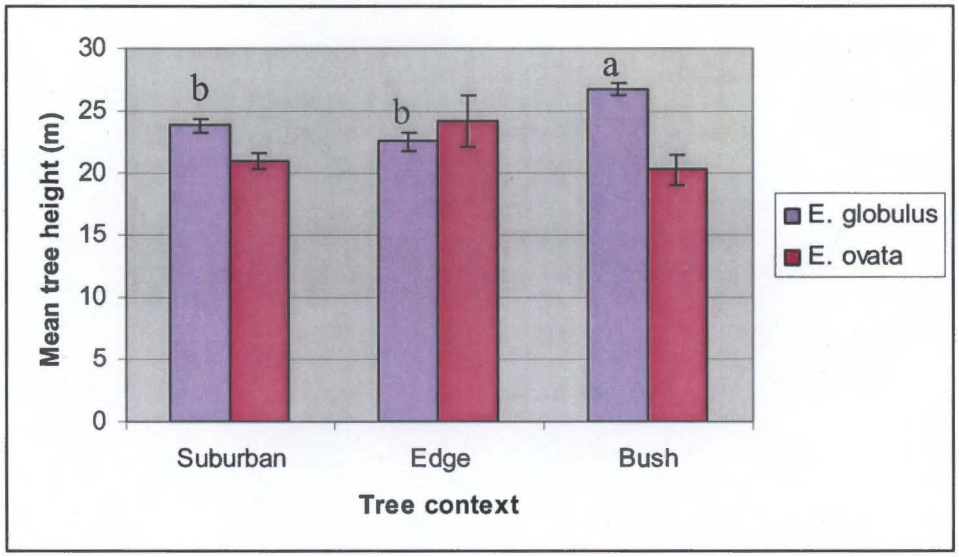


Figure 9. Comparison of the mean tree height of both *E. globulus* and *E. ovata* in the three tree contexts. Standard errors shown. Pair-wise differences between conspecifics in the three contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

The mean number of *E. globulus* opercula was regressed against the tree height, which showed no significant relation between those two variables ($r^2 = 1.7\%$; Figure 10).

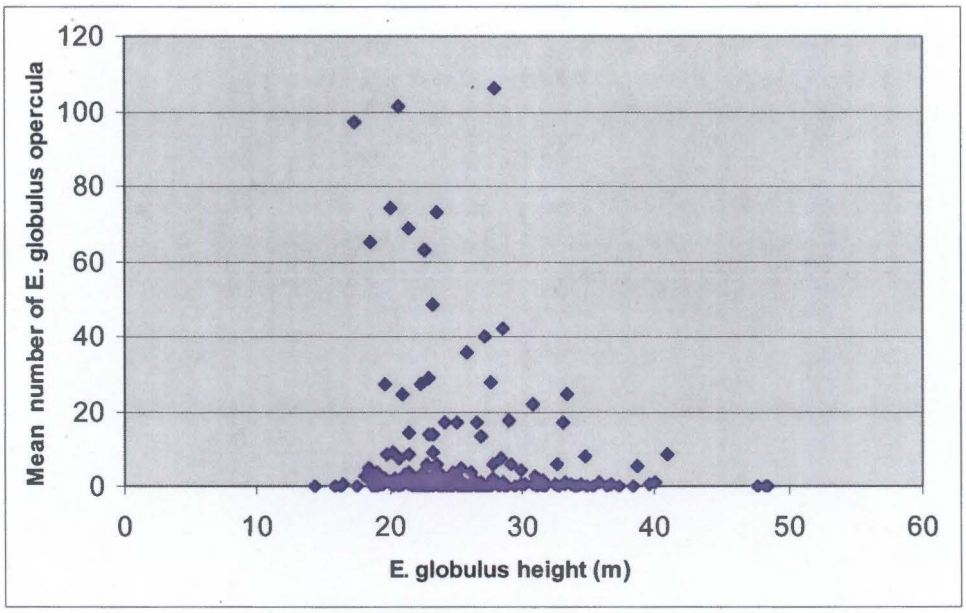


Figure 10. Comparison of *E. globulus* mean opercula number per square metre and tree height.

No significant difference in the mean tree height was found among the various categories of capsule loads for *E. globulus* ($H_4 = 4.26$, $P = 0.37$) or *E. ovata* ($H_4 = 5.01$, $P = 0.29$) (Figure 11). Trees of similar heights had quite different capsule loads, ranging from 0% to > 70% (Figure 11).

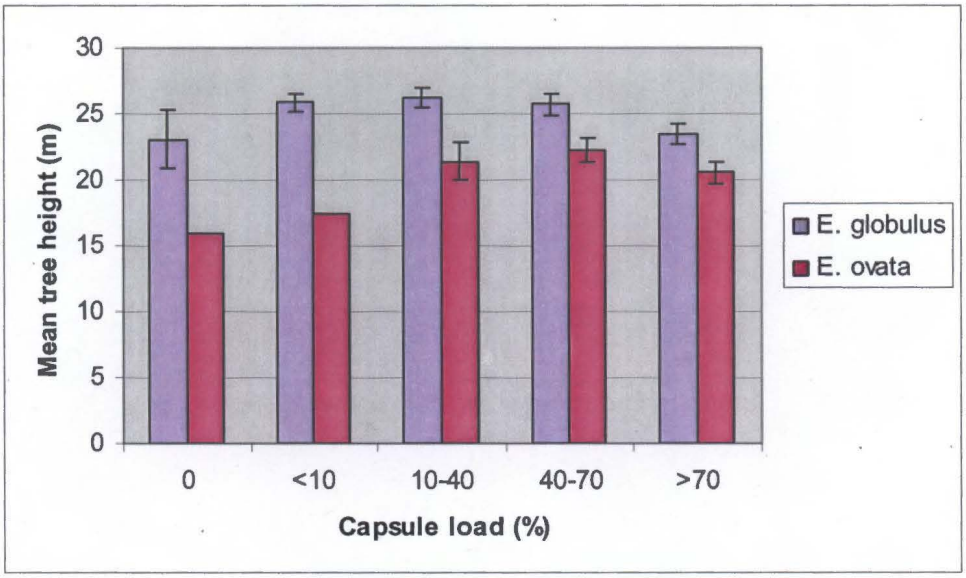


Figure 11. Comparison of the mean height and capsule load for both *E. globulus* and *E. ovata*. Standard errors shown.

3.3.2 Tree basal area

The difference in the mean basal area of *E. globulus* among the three contexts was statistically significant ($H_2 = 7.42$, $P = 0.024$; Figure 12). Post hoc pair-wise tests revealed no significant differences in tree basal area between edge and bush trees ($P = 0.34$). However, pair-wise differences between suburban and edge trees ($P = 0.017$), and between suburban and bush trees ($P = 0.02$; $\alpha = 0.0167$ after Bonferroni adjustment) approached significance, with suburban trees being slightly larger than those in the other two contexts. A significant difference was also recorded for *E. ovata* basal area among the three contexts ($H_2 = 11.19$, $P = 0.004$; Figure 12). Post hoc pair-wise tests showed a significant difference in basal area between suburban and bush *E. ovata* ($P = 0.002$), with the former being larger. No significant differences were recorded between suburban and edge trees ($P = 0.089$), or between edge and bush trees ($P = 0.39$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 12).

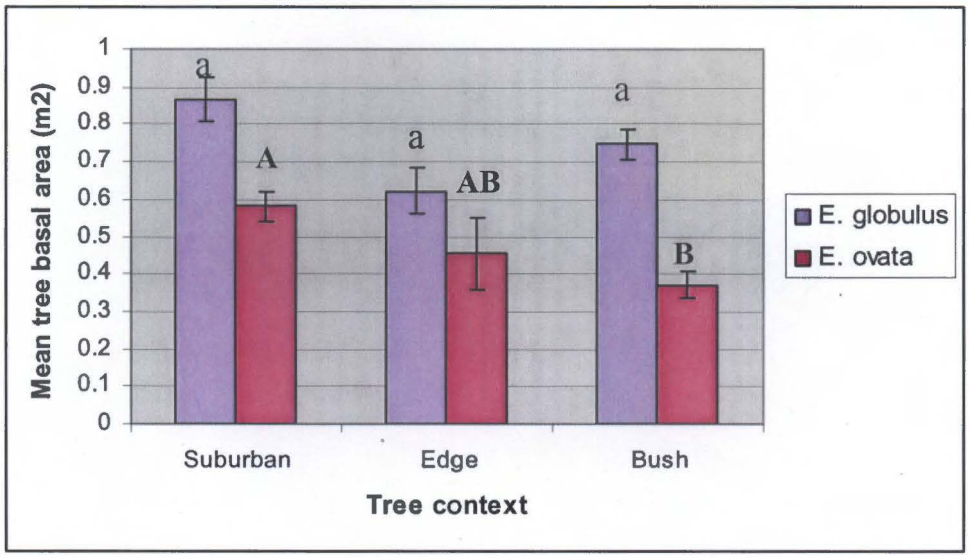


Figure 12. Comparison of the mean basal area for both *E. globulus* and *E. ovata* in the three tree contexts. Standard errors shown. Pair-wise differences between conspecifics in the three contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.0167$ following Bonferroni adjustment).

There was no association between *E. globulus* basal area and the mean number of *E. globulus* opercula ($r^2 = 1.6\%$; Figure 13).

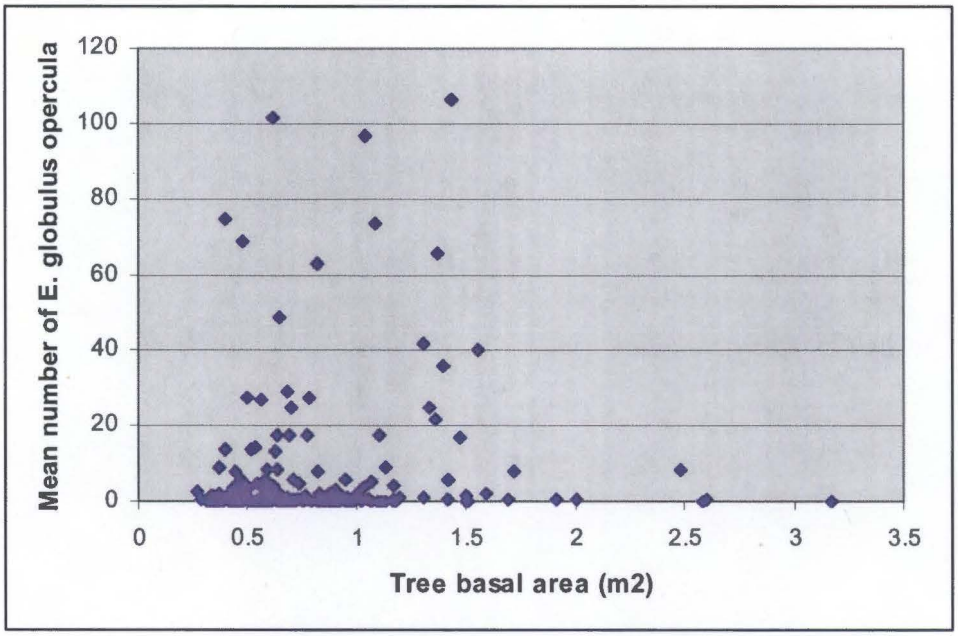


Figure 13. Comparison of *E. globulus* mean opercula number per square metre and tree basal area.

There was no significant difference in the mean basal area among the various categories of capsule loads of *E. globulus* ($H_4 = 2.08$, $P = 0.72$; Figure 14). Trees with similar basal areas were found with capsule loads ranging from 0% to > 70%. Similarly, the difference in the mean basal area among the various categories of capsule loads of *E. ovata* was also non-significant ($H_4 = 8.62$, $P = 0.071$; Figure 14).

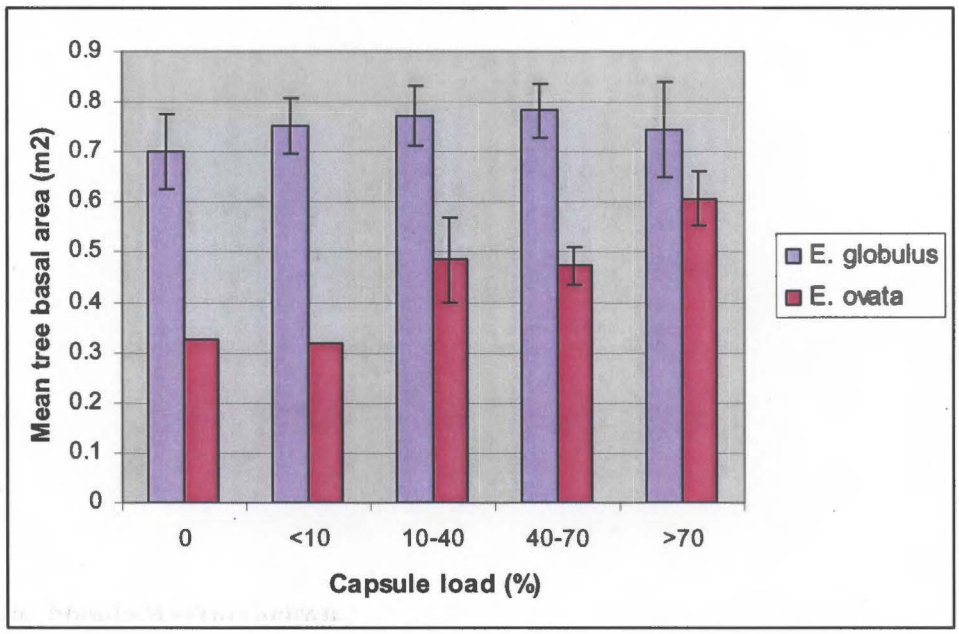


Figure 14. Comparison of the mean basal area and capsule load for both *E. globulus* and *E. ovata*. Standard errors shown.

3.3.3 Canopy density

The mean ranks of canopy density for each species of eucalypt were significantly different among the three contexts (*E. globulus* $H_2 = 13.39$, $P = 0.001$; *E. ovata* $H_2 = 9.06$, $P = 0.011$; Figure 15). Post hoc pair-wise tests revealed that the only significant differences in canopy density were between suburban and bush trees for each eucalypt species (*E. globulus* $P = 0.0005$; *E. ovata* $P = 0.003$), with suburban trees having denser canopies (Figure 15). The remaining differences between suburban and edge trees (*E. globulus* $P = 0.3$; *E. ovata* $P = 0.85$), and edge and bush (*E. globulus* $P = 0.12$; *E. ovata* $P = 0.07$) were non-significant ($\alpha = 0.017$ after Bonferroni adjustment; Figure 15).

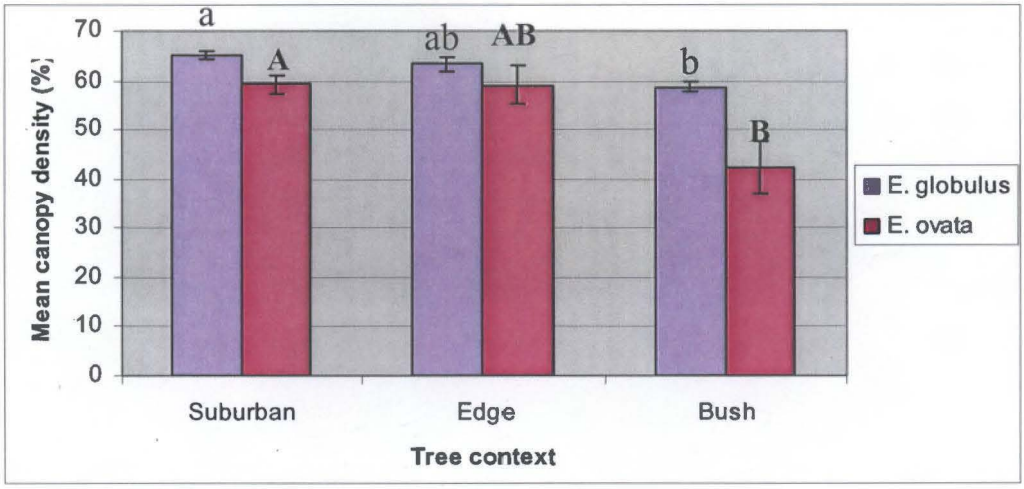


Figure 15. Comparison of the mean canopy density in the three tree contexts for both *E. globulus* and *E. ovata*. Standard errors shown. Pair-wise differences between conspecifics in the three contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

There was a significant difference in the mean *E. globulus* opercula number among canopy density classes ($H_2 = 21.98$, $P < 0.001$; Figure 16). Post hoc pair-wise tests showed that there were significant differences in opercula number between canopy densities of < 49% and 50-60% ($P = 0.001$), and < 49% and > 61% ($P < 0.0001$); with the number of opercula being higher in denser canopies. The difference between canopy density of 50-60% and > 60% approached significance ($P = 0.022$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 16).

The study showed a significant difference in the mean ranks of canopy density among different capsule load classes for each species of eucalypt (*E. globulus* $H_4 = 10.91$, $P = 0.028$; *E. ovata* $H_4 = 12.32$, $P = 0.015$; Figure 17). Post hoc pair-wise tests revealed that the only significant difference in canopy density for *E. globulus* was between trees with < 10% and > 70% capsule load ($P = 0.0038$; $\alpha = 0.005$ after Bonferroni adjustment); whereby trees with > 70% capsule loads had the most dense canopies. For *E. ovata*, a significant difference was observed between trees with 10-40% and > 70% capsule load ($P = 0.0095$; $\alpha = 0.017$ after Bonferroni adjustment); whereby, similar to *E. globulus*, trees with the highest capsule loads (> 70%) had also the most dense canopies. The remaining differences in the capsule load were non-significant for each eucalypt species (Figure 17).

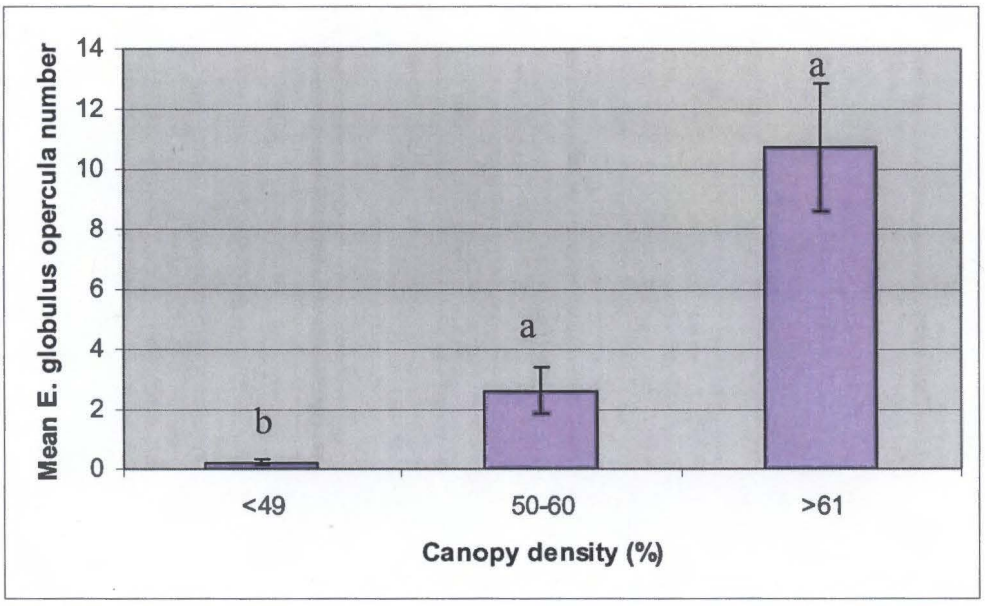


Figure 16. Comparison of *E. globulus* mean opercula number per square metre and canopy density. Standard errors shown. Pair-wise differences between canopy density classes, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

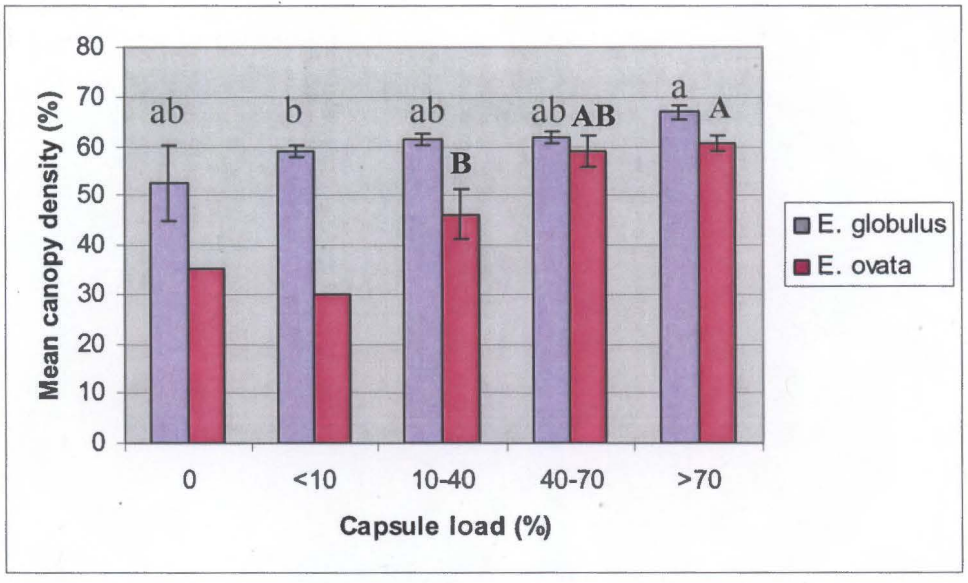


Figure 17. Comparison of the mean canopy density and capsule load for both *E. globulus* and *E. ovata*. Standard errors shown. Pair-wise differences between conspecifics in the capsule load classes, as determined by Mann-Whitney U-tests, denoted by different letters (*E. globulus* $\alpha = 0.005$ and *E. ovata* $\alpha = 0.017$, following Bonferroni adjustment). Capsule load classes of 0% and < 10% for *E. ovata* were excluded from the post hoc tests due to insufficient data.

3.3.4 Tree dieback

There was a statistically significant difference in tree dieback of *E. globulus* among the three contexts ($H_2 = 35.64$, $P < 0.001$; Figure 18). Post hoc pair-wise tests revealed significant differences for *E. globulus* dieback between suburban and bush ($P < 0.0001$), and suburban and edge contexts ($P = 0.016$). However, no significant difference in tree dieback was noted between edge and bush contexts ($P = 0.068$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 18). The health of suburban trees was better than trees in the other two contexts, with more than 90% of suburban trees recorded as healthy. Moreover, no trees showing signs of advanced senescence were found in the suburban context. Edge and bush trees, however, carried more evidence of dieback, senescence and advanced senescence (Figure 18).

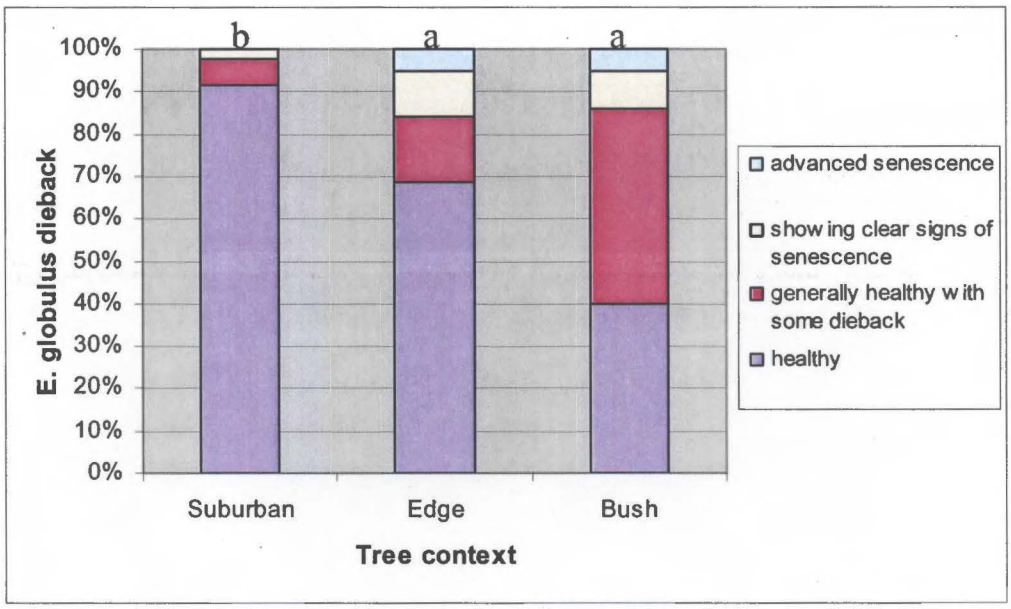


Figure 18. Comparison of *E. globulus* dieback in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

In addition, a significant difference in *E. ovata* dieback among the three contexts was found ($H_2 = 17.03$, $P < 0.001$; Figure 19). Post hoc pair-wise tests revealed a significant difference in dieback of *E. ovata* trees between suburban and bush contexts ($P < 0.0001$). Suburban trees were predominantly healthy; whereas a larger proportion of bush trees showed signs of dieback or senescence (Figure 19).

However, there was no significant difference in tree dieback between suburban and edge trees (P = 0.47), or bush and edge trees (P = 0.03; α = 0.017 after Bonferroni adjustment).

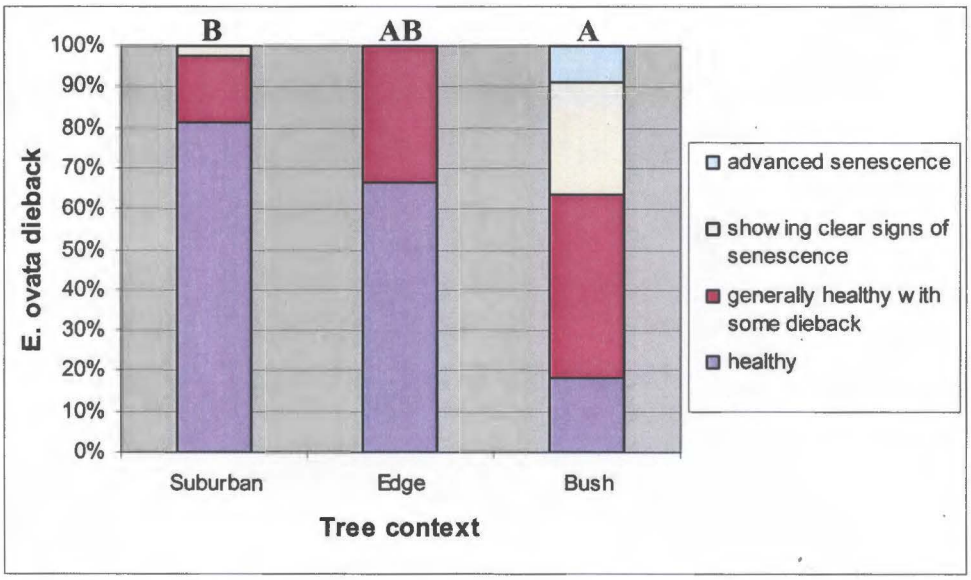


Figure 19. Comparison of *E. ovata* dieback in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters (α = 0.017, following Bonferroni adjustment).

A significant difference was found in the mean number of *E. globulus* opercula among the various classes of tree dieback (H_3 = 22.49, P < 0.001; Figure 20). Post hoc pair-wise tests revealed significant differences in opercula numbers between healthy and generally healthy trees with some dieback (P = 0.0008), as well as healthy trees and trees showing signs of advanced senescence (P = 0.0011; α = 0.008 after Bonferroni adjustment); with healthy trees having much higher opercula numbers (Figure 20). The remaining differences in the numbers of opercula between the dieback classes were non-significant (Figure 20).

A significant difference was found in capsule load among the various classes of *E. globulus* dieback (H_3 = 14.21, P = 0.003; Figure 21). Post hoc pair-wise tests revealed significant differences in capsule load between healthy trees and trees of advanced senescence (P = 0.0048), and between generally healthy trees with some dieback and trees of advanced senescence (P = 0.0071; α = 0.008 after Bonferroni adjustment). As shown in Figure 21, healthy trees and generally healthy trees with

some dieback were found to carry the biggest capsule loads; whereas almost 38% of trees showing signs of advanced senescence had no capsules. There were no significant differences for the remaining comparisons between the dieback classes (Figure 21).

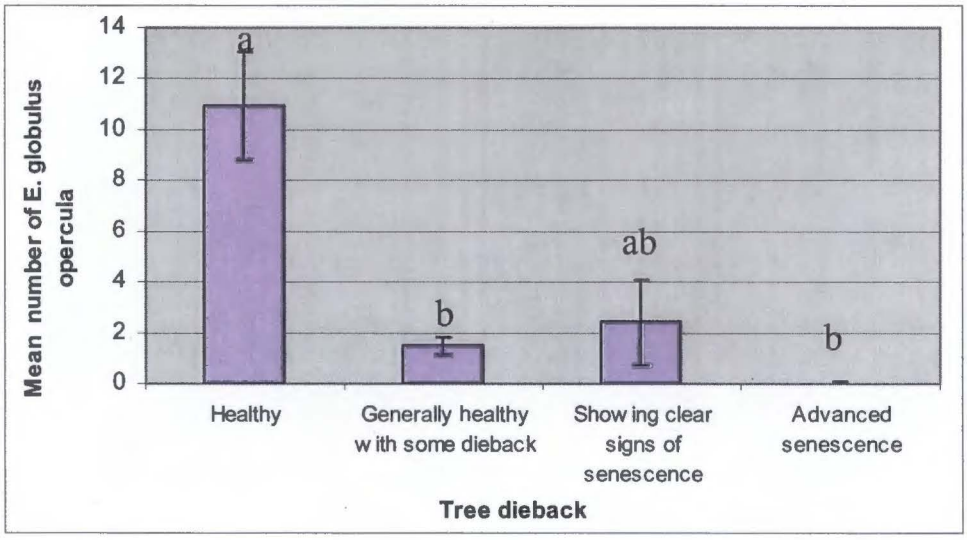


Figure 20. Comparison of *E. globulus* mean opercula number per square metre and tree dieback. Standard errors shown. Pair-wise differences between dieback classes, as determined by Mann-Whitney U-tests, denoted by different letters (α = 0.008, following Bonferroni adjustment).

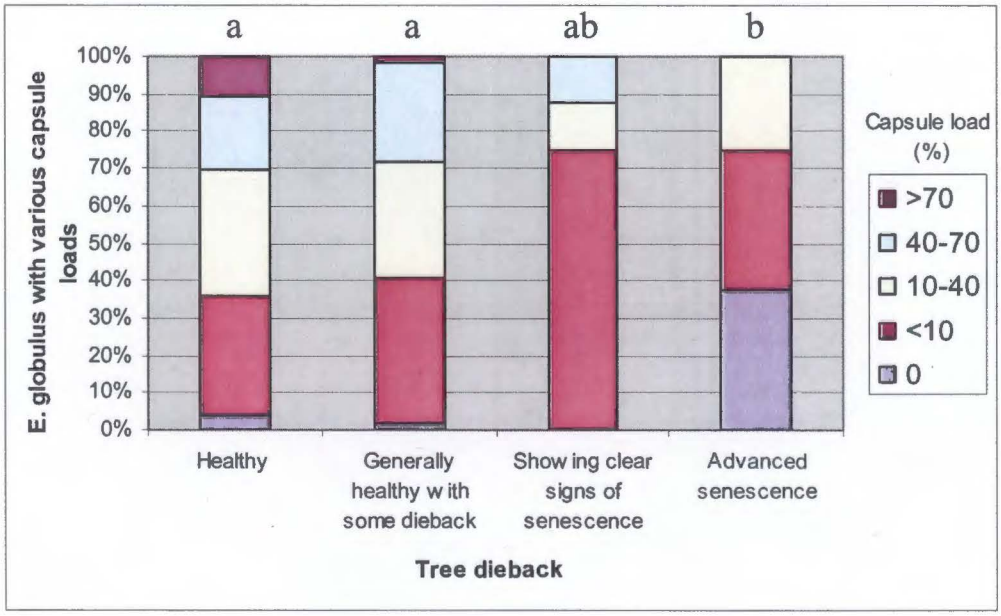


Figure 21. Comparison of *E. globulus* capsule loads and tree dieback. Pair-wise differences between dieback classes, as determined by Mann-Whitney U-tests, denoted by different letters (α = 0.008, following Bonferroni adjustment).

There was a statistically significant difference in *E. ovata* capsule load among the various classes of tree dieback ($H_3 = 12.25$, $P = 0.007$; Figure 22). Post hoc pair-wise tests showed a significant difference in capsule load between healthy trees and generally healthy trees with some dieback ($P = 0.0088$); whereby healthy trees had more capsules (Figure 22). The differences between healthy trees and trees showing clear signs of senescence, or generally healthy trees with some dieback and trees showing clear signs of senescence were both non-significant ($P = 0.051$ and $P = 0.27$ respectively; $\alpha = 0.017$ after Bonferroni adjustment; Figure 22). More than 55% of healthy trees were found with capsule loads of > 70%. Also, the majority of generally healthy *E. ovata* with some dieback (62%) had relatively high capsule loads (40-70%). However, 75% of trees showing clear signs of senescence had capsule loads of < 40%. None of the trees showing advanced senescence bore any capsules, but the number of trees in this dieback class was insufficient for valid pair-wise comparisons with other classes (Figure 22).

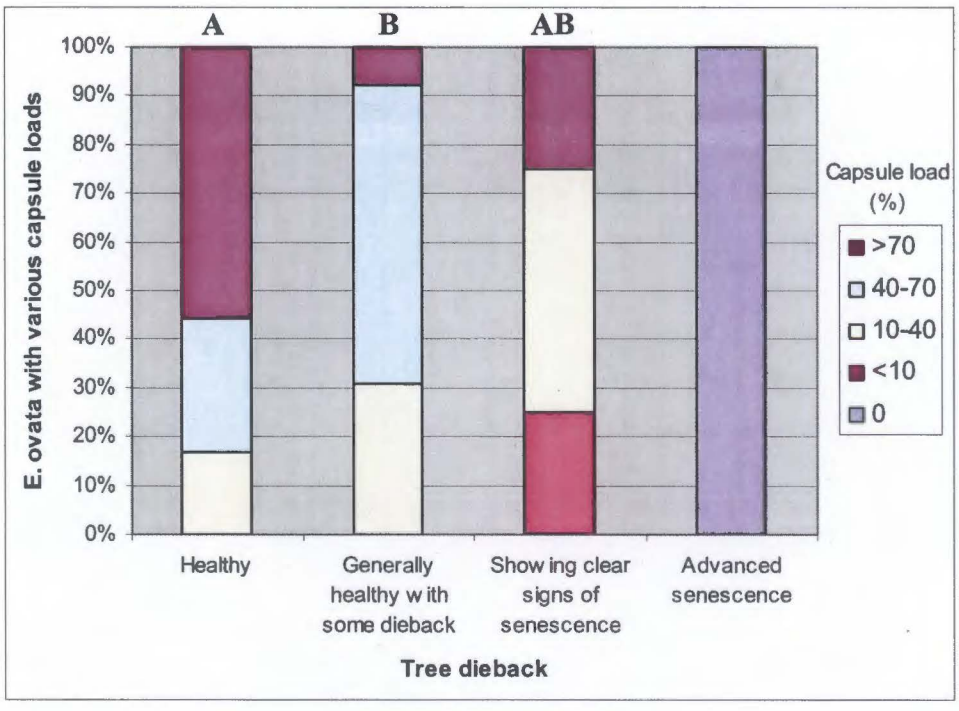


Figure 22. Comparison of *E. ovata* capsule loads and tree dieback. Pair-wise differences between dieback classes, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment). The 'advanced senescence' class was excluded from the post hoc tests due to insufficient data.

3.3.5 The percentage of branches that were dead

The difference in the percentage of branches that were dead among the three contexts for *E. globulus* was significant ($H_2 = 46.27$, $P < 0.001$; Figure 23). Post hoc pair-wise tests showed that there were significant differences in the percentages of branches that were dead between suburban and bush *E. globulus* ($P < 0.0001$), suburban and edge ($P = 0.013$), and edge and bush ($P = 0.0092$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 23). Almost 90% of recorded suburban trees had fewer than 5% of branches in the canopy dead; while this figure was 63% for edge trees, and 30% for bush trees (Figure 23).

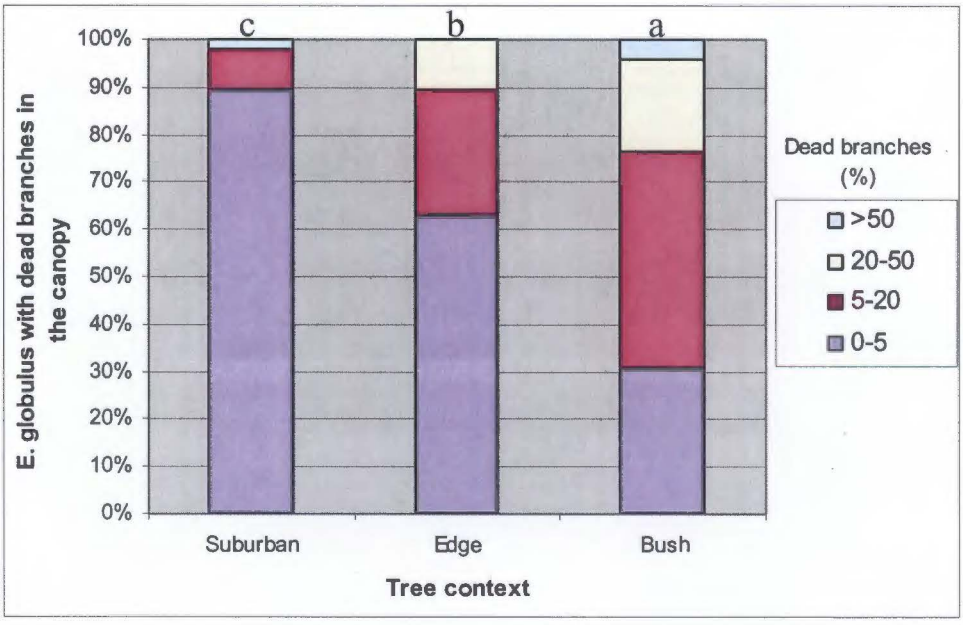


Figure 23. Comparison of *E. globulus* with various percentages of branches in the canopy that were dead, in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

Also, a significant difference was found in the percentage of branches that were dead among the three contexts for *E. ovata* ($H_2 = 23.01$, $P < 0.001$; Figure 24). Post hoc pair-wise tests revealed significant differences in the percentage of branches that were dead between suburban and bush *E. ovata* ($P < 0.0001$), and suburban and edge ($P = 0.0025$; $\alpha = 0.017$ after Bonferroni adjustment). Suburban trees had a smaller percentage of branches that were dead than the other two contexts.

Almost 90% of suburban *E. ovata* had 0-5% of branches in the canopy dead; whereas only 33% of edge and 18% of bush trees were recorded with the lowest percentage category of branches that were dead (Figure 24). No suburban *E. ovata* trees were found with more than 20% of branches dead. Bush trees, unlike trees in the other two contexts, were sometimes recorded with more than 50% of branches in the canopy dead. The difference in the percentage of branches that were dead between the edge and bush trees was non-significant (P = 0.36; Figure 24).

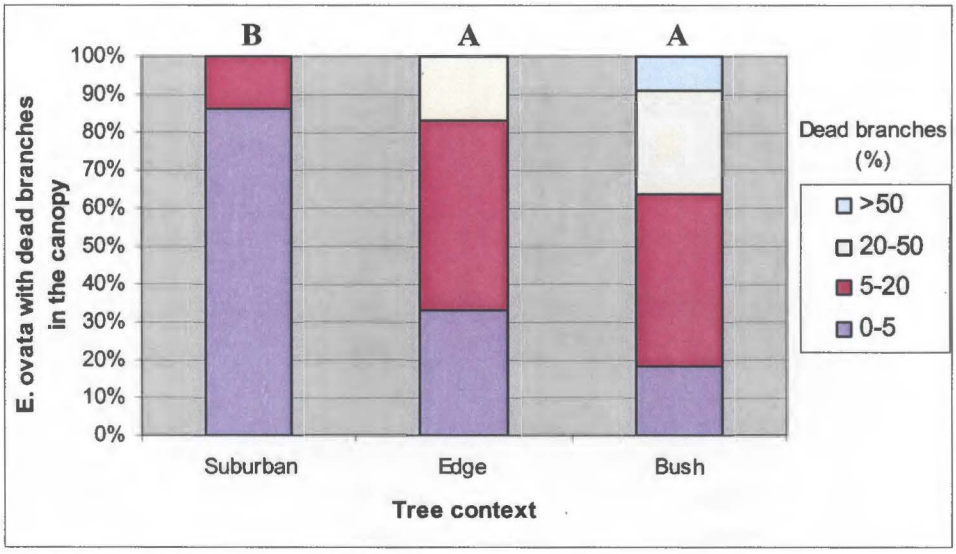


Figure 24. Comparison of *E. ovata* with various percentages of branches in the canopy that were dead, in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters (α = 0.017, following Bonferroni adjustment).

There was a significant difference in the mean *E. globulus* opercula number among various classes of the percentage of branches that were dead in the tree canopy ($H_3 = 15.77$, P = 0.001; Figure 25). As shown in Figure 25, trees with the smallest proportion of branches that were dead (0-5%) had the greatest number of opercula. Post hoc pair-wise tests revealed that significant differences in the number of opercula occurred between trees with 0-5% and 5-20% of branches that were dead (P = 0.0038), as well as 0-5% and 20-50% of branches that were dead (P = 0.0055; α = 0.008 after Bonferroni adjustment). No significant differences were found between the remaining classes of the percentage of branches that were dead (Figure 25).

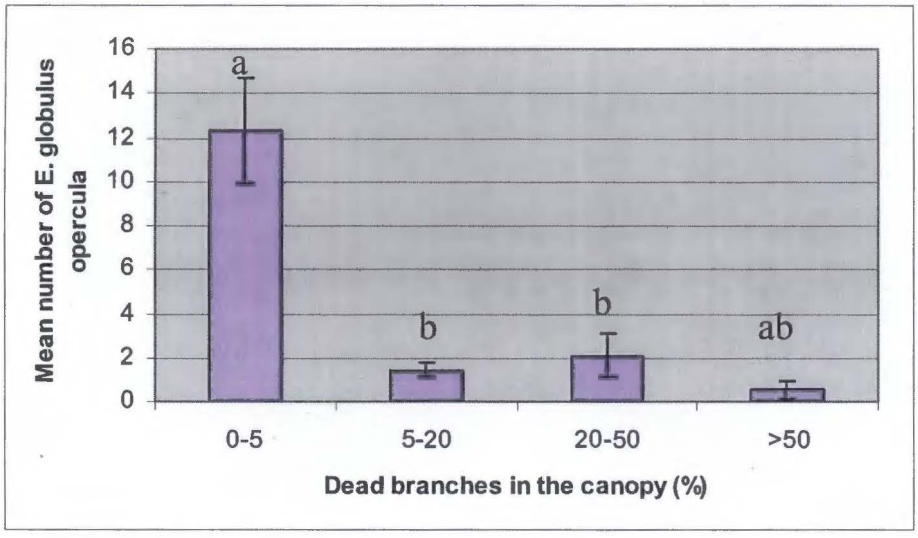


Figure 25. Comparison of *E. globulus* mean opercula number per square metre and the percentage of branches in the canopy that were dead. Standard errors shown. Pair-wise differences between classes of the percentage of dead branches, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

No significant difference in *E. globulus* capsule load was recorded among the classes of the percentage of branches in the canopy that were dead ($H_3 = 5.99$, $P = 0.112$; Figure 26). Nevertheless, Figure 26 shows a weak trend towards more capsules when the percentage of branches that were dead is lower. The majority of trees with 0-5% and 5-20% of branches that were dead had > 10% of the maximum number of capsules; whereas the majority of trees with 20-50% and > 50% of branches in the canopy dead had < 10% of the maximum number of capsules.

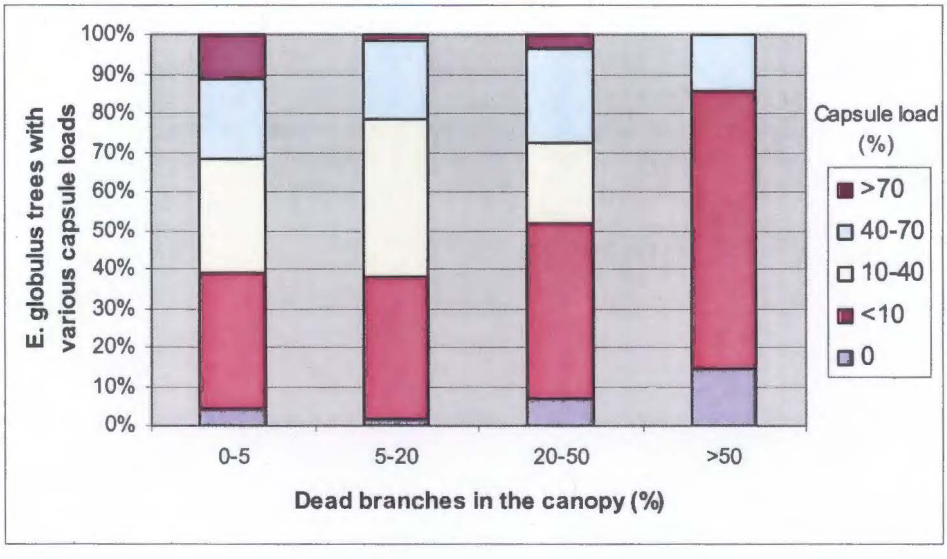


Figure 26. Comparison of *E. globulus* capsule loads and the percentage of branches in the canopy that were dead.

There was a statistically significant difference in *E. ovata* capsule load among various classes of the percentage of branches in the canopy that were dead ($H_3 = 9.39$, $P = 0.025$; Figure 27). The majority (56%) of *E. ovata* trees with the least amount of branches that were dead (0-5%) was recorded with the greatest capsule loads (> 70%). In general, trees with a greater percentage of branches in the canopy that were dead were found with smaller capsule loads. Capsule loads of > 70% were not recorded in trees with 20-50% and > 50% of branches in the canopy dead. Moreover, there were no capsules found in trees with > 50% of branches dead (Figure 27). However, post hoc pair-wise tests showed no significant differences in capsule loads between trees with different proportions of branches that were dead. The P-value for the differences between trees with 0-5% and 5-20% of branches that were dead was 0.059; for 5-20% and 20-50%, $P = 0.33$; and for 0-5% and 20-50%, $P = 0.052$ ($\alpha = 0.017$ after Bonferroni adjustment; Figure 27). However, the number of trees in the class of > 50% of branches that were dead was insufficient for valid pair-wise comparisons with other classes.

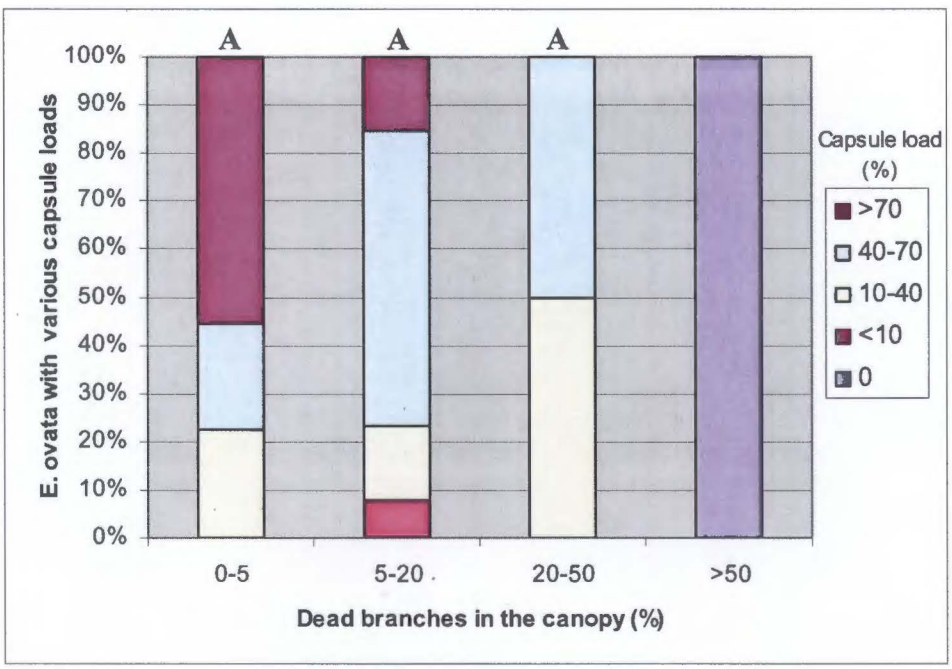


Figure 27. Comparison of *E. ovata* capsule loads and the percentage of branches in the canopy that were dead Pair-wise differences between the classes of the percentage of dead branches, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment). The class of > 50% of dead branches was excluded from the post hoc tests due to insufficient data.

3.4 Environmental tree variables

3.4.1 Moisture Index (MI) based on aspect

There was a highly significant result for the difference in Moisture Index based on aspect among the three contexts for *E. globulus* ($H_2 = 27$, $P < 0.001$; Figure 28). Post hoc pair-wise tests showed that there were significant differences in Moisture Index based on aspect between suburban and bush *E. globulus* ($P < 0.0001$), as well as edge and bush ($P = 0.0019$). The majority of suburban and edge trees were found on westerly to northerly aspects; whereas a greater proportion of bush trees occurred on moister aspects receiving less solar radiation (Figure 28). There was no significant difference between Moisture Indices for suburban and edge trees ($P = 0.51$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 28).

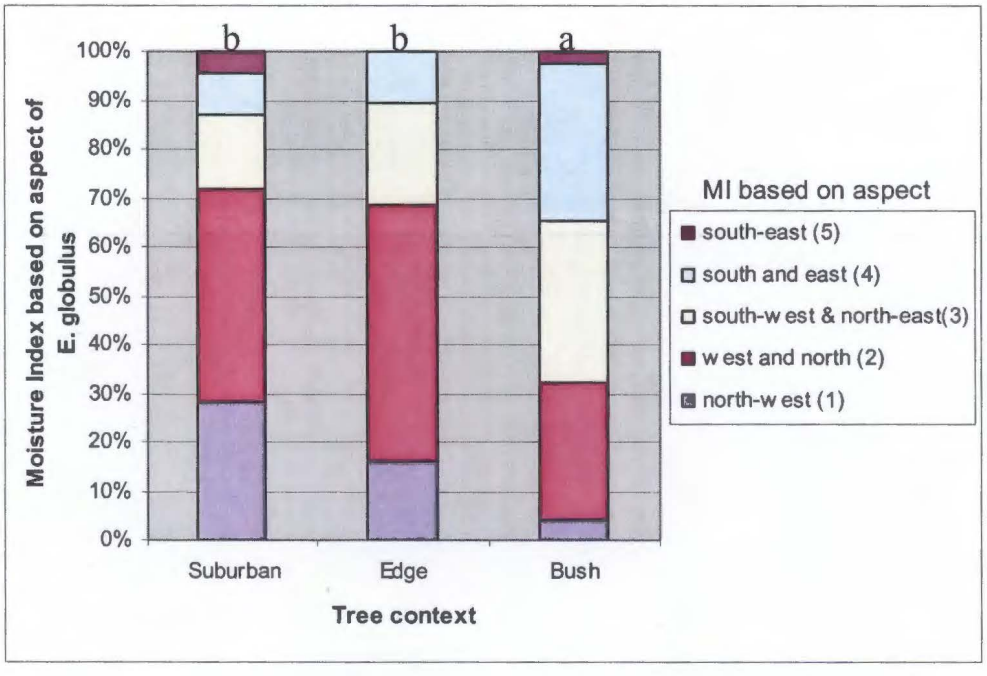


Figure 28. Comparison of Moisture Indices based on aspect for *E. globulus* in the three tree contexts. The figure excludes trees from sites with slopes of zero degrees. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

The difference in Moisture Index based on aspect among the three contexts for *E. ovata* was non-significant ($H_2 = 1.69$, $P = 0.43$; Figure 29). Figure 29 indicates that most *E. ovata* trees in all three contexts grew on northern to western slopes.

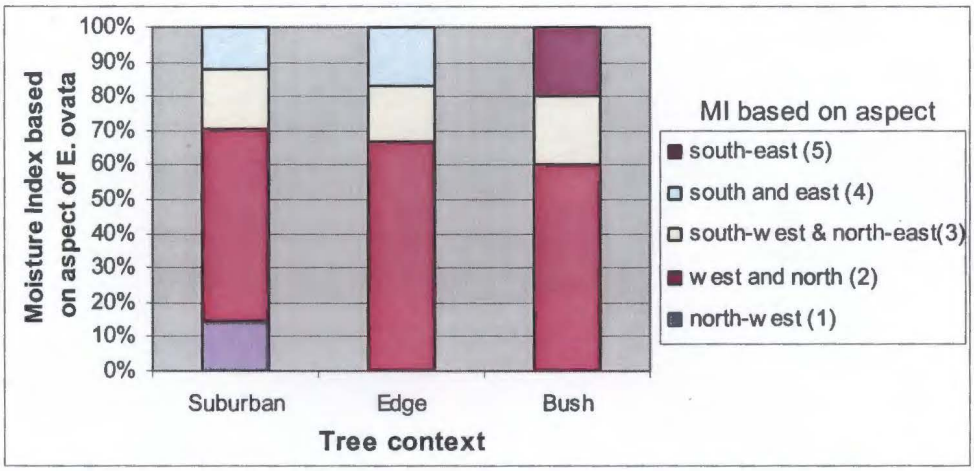


Figure 29. Comparison of Moisture Indices based on aspect for *E. ovata* in the three tree contexts. The figure excludes trees from sites with slopes of zero degrees.

The difference in the mean number of *E. globulus* opercula among the Moisture Indices based on aspect was highly significant ($H_4 = 27.09$, $P < 0.001$; Figure 30). Post hoc pair-wise tests revealed that there were significant differences in the numbers of opercula between trees with MI = 1 and MI = 3 ($P < 0.0001$), MI = 1 and MI = 4 ($P < 0.0001$), and MI = 2 and MI = 4 ($P = 0.0028$; $\alpha = 0.005$ after Bonferroni adjustment). The remaining differences between Moisture Indices were statistically non-significant (Figure 30). Figure 30 shows that the highest numbers of opercula were recorded on aspects with low MI (MI = 1-2). The trees found in aspect classes with MI = 3-5 all had a very low mean opercula number (< 5).

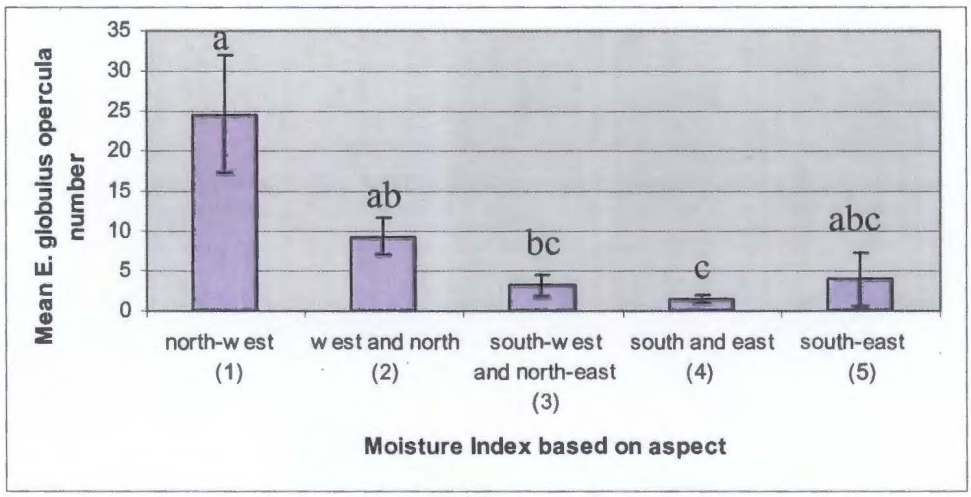


Figure 30. Comparison of *E. globulus* mean opercula number per square metre and Moisture Indices based on aspect. Standard errors shown. The figure excludes trees from sites with slopes of zero degrees. Pair-wise differences between Moisture Indices, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.005$, following Bonferroni adjustment).

There was no significant difference in the observed capsule loads among the Moisture Indices based on aspect for either species of eucalypt (*E. globulus* $H_4 = 3.28$, $P = 0.51$; Figure 31, and *E. ovata* $H_4 = 2.65$, $P = 0.61$; Figure 32).

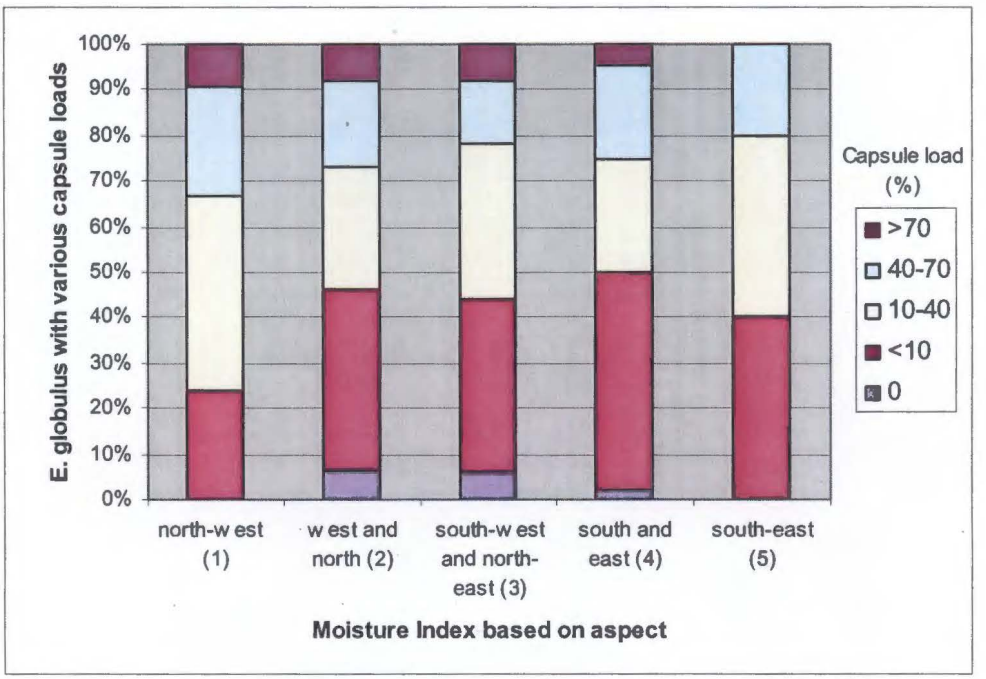


Figure 31. Comparison of *E. globulus* capsule loads and Moisture Indices based on aspect. The figure excludes trees from sites with slopes of zero degrees.

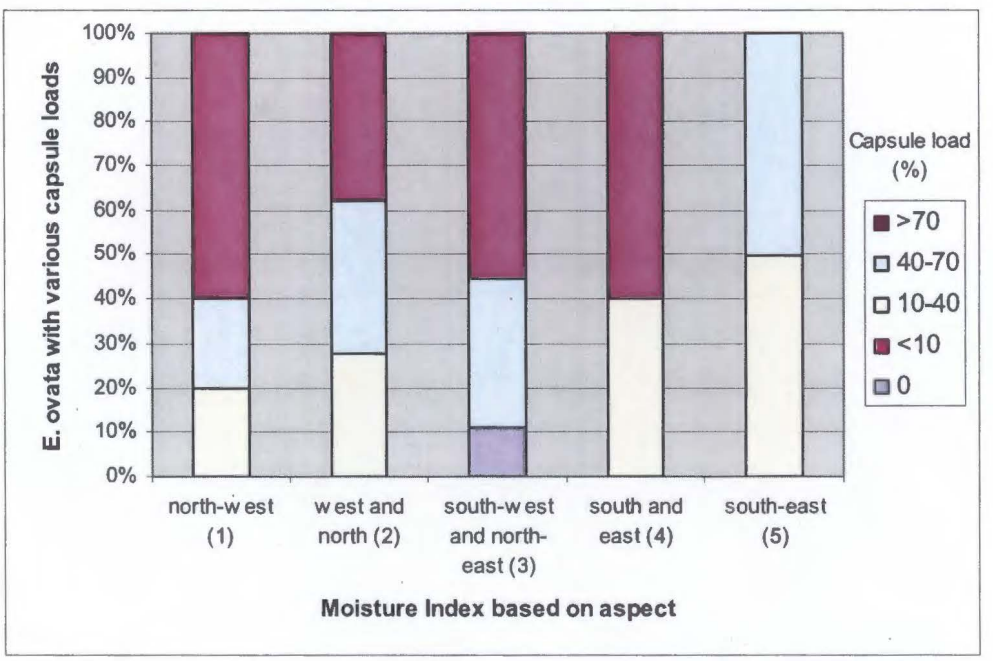


Figure 32. Comparison of *E. ovata* capsule loads and Moisture Indices based on aspect. The figure excludes trees from sites with slopes of zero degrees.

3.4.2 Slope

There was a significant difference in the mean ground slope for *E. globulus* trees among the three contexts ($H_2 = 31.29$, $P < 0.001$; Figure 33); however for *E. ovata* it was non-significant ($H_2 = 3.47$, $P = 0.17$; Figure 33). Post hoc pair-wise tests showed significant differences in ground slope between suburban and bush *E. globulus* ($P < 0.0001$), as well as edge and bush ($P = 0.0019$). Figure 33 indicates that *E. globulus* trees in the bush were located on steeper slopes (with the average value of 13.5°) than their edge or suburban counterparts. No significant difference, however, was recorded between suburban and edge trees ($P = 0.44$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 33).

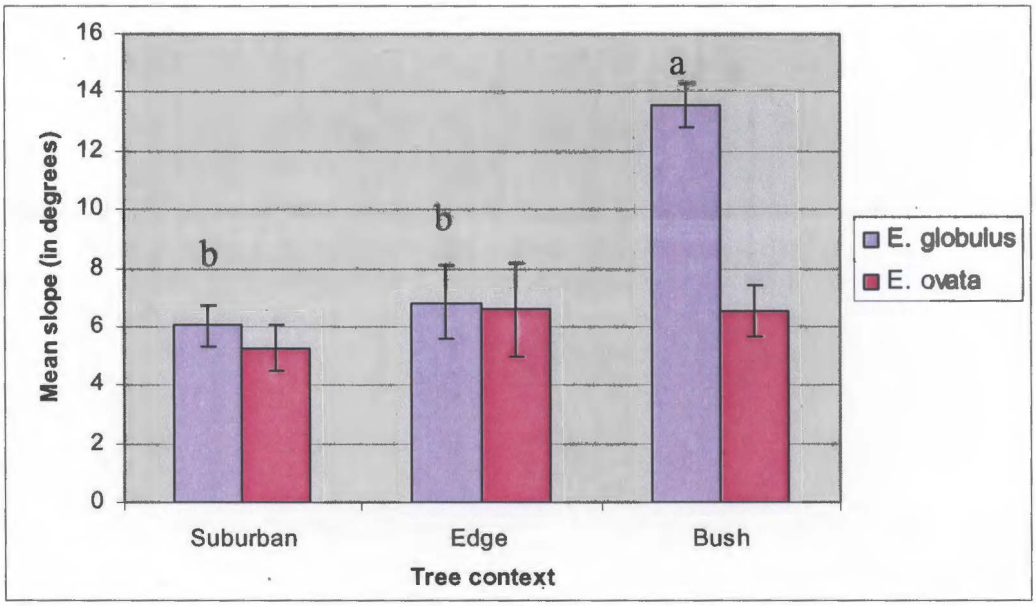


Figure 33. Comparison of the mean ground slope for both *E. globulus* and *E. ovata* in the three tree contexts. Standard errors shown. Pair-wise differences between conspecifics in the three contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

There was no significant relationship between the number of *E. globulus* opercula and ground slope ($r^2 = 3.4\%$; Figure 34).

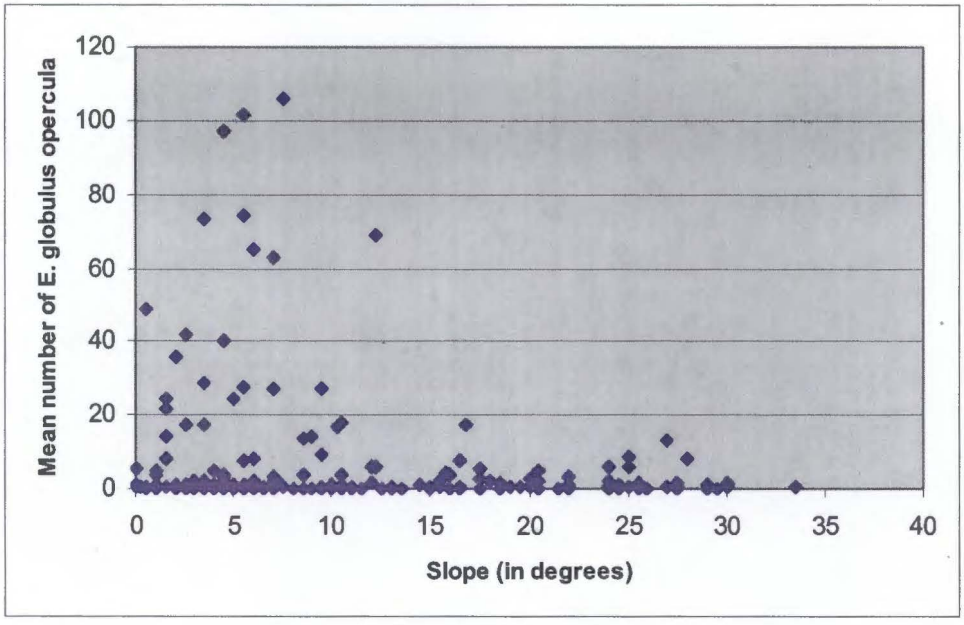


Figure 34. Comparison of *E. globulus* mean opercula number per square metre and ground slope.

Moreover, no significant differences were found in the mean ground slope among the various capsule load classes of *E. globulus* and *E. ovata* (*E. globulus* $H_4 = 2.64$, $P = 0.62$; *E. ovata* $H_4 = 4.55$, $P = 0.33$; Figure 35).

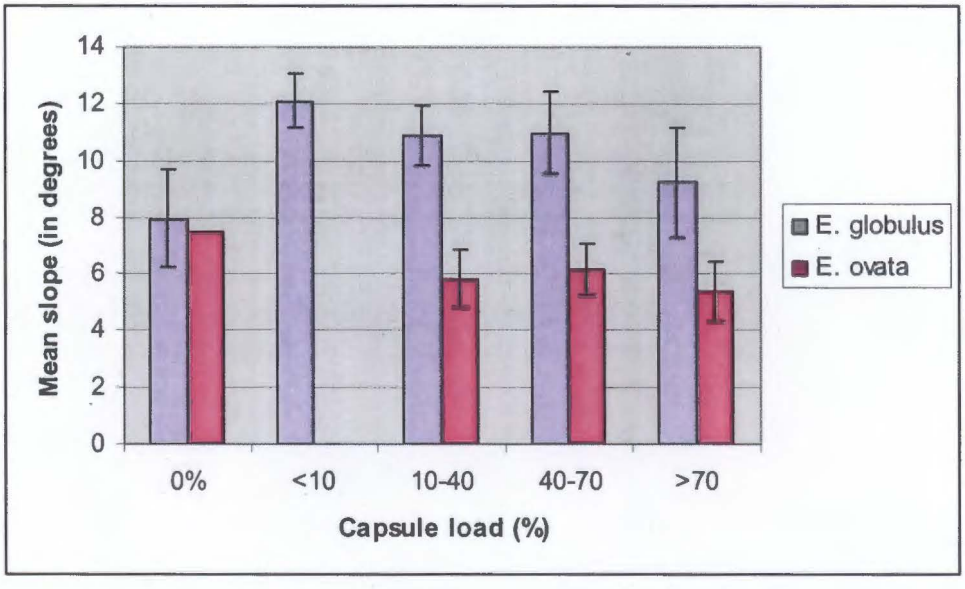


Figure 35. Comparison of the mean ground slope and capsule load for both *E. globulus* and *E. ovata*. Standard errors shown.

3.4.3 Topography

The difference in topography among the three contexts for *E. globulus* was highly significant ($H_2 = 52.85$, $P < 0.001$; Figure 36). Post hoc pair-wise tests showed highly significant differences in topography between suburban and bush *E. globulus* ($P < 0.0001$), as well as edge and bush ($P < 0.0001$; $\alpha = 0.017$ after Bonferroni adjustment). Thirty-four per cent of bush *E. globulus* occurred in a gully. Since there was no suburban development in any of the gullies of Mount Nelson, no suburban or edge trees were recorded in gullies. However, the majority of *E. globulus* trees in all three contexts were found either along the ridge or in the upper slope of Mount Nelson (Figure 36). No significant difference in topography was recorded between suburban and edge trees ($P = 0.98$; Figure 36).

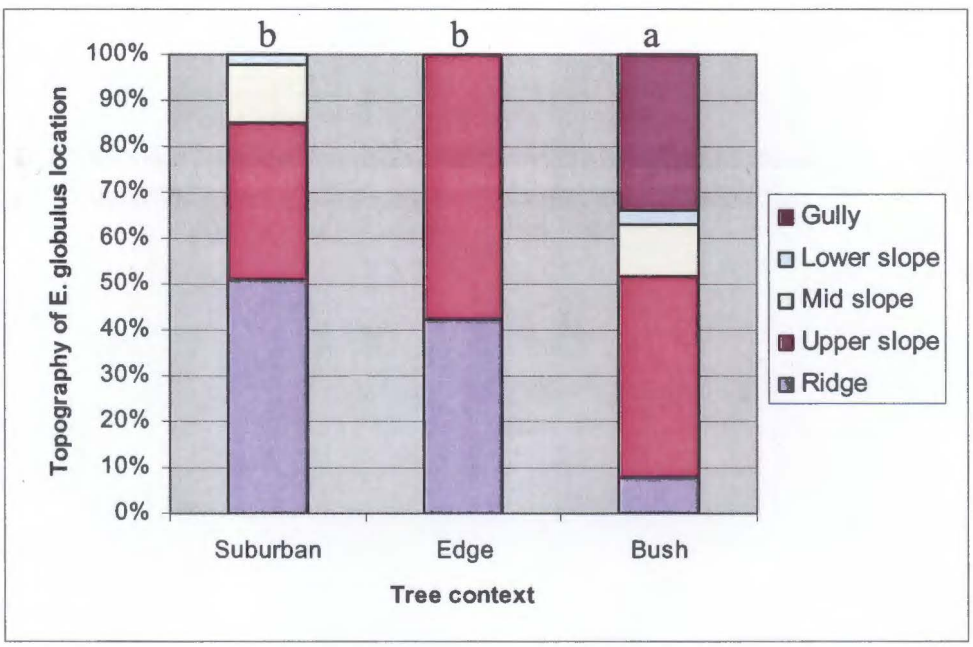


Figure 36. Comparison of topography classes for *E. globulus* in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

Similarly to *E. globulus*, the difference in topography among the three contexts for *E. ovata* was highly significant ($H_2 = 20.91$, $P < 0.001$; Figure 37). Post hoc pair-wise tests revealed significant differences in topography between suburban and bush *E. ovata* ($P < 0.0001$), as well as edge and bush ($P = 0.0065$; $\alpha = 0.017$ after Bonferroni adjustment). Ninety-four per cent of suburban trees were found on the ridge and upper slope; and all edge trees occurred in those two topography classes. However, no bush trees were recorded on the ridge and only 27% occurred on the upper slope. A high proportion (55%) of bush *E. ovata* was found in gullies, but no suburban or edge trees were recorded in gullies (Figure 37). There was no significant difference in topography between suburban and edge trees ($P = 0.33$; Figure 37).

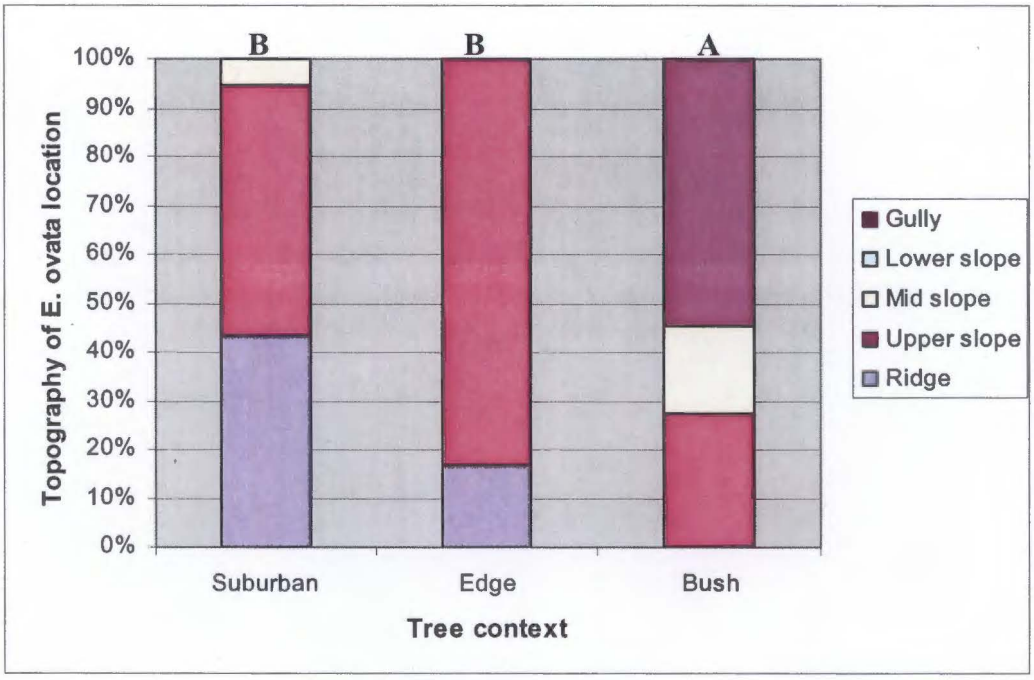


Figure 37. Comparison of topography classes for *E. ovata* in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

No significant difference was found in the mean opercula number among topography classes for *E. globulus* ($H_4 = 8.6$, $P = 0.072$; Figure 38). Although the mean number of opercula was the highest on the lower slope and the ridge, there was a great deal of variation among trees in these topographic classes (Figure 38).

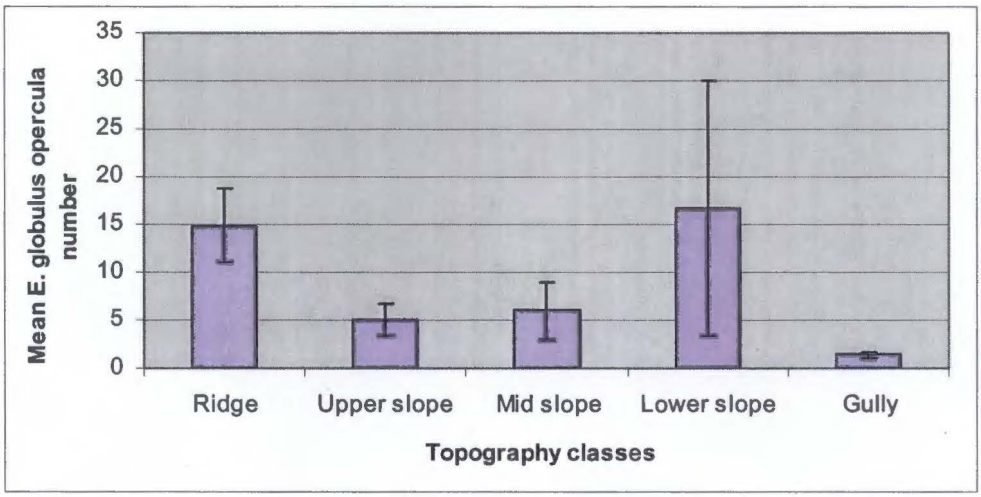


Figure 38. Comparison of *E. globulus* mean opercula number per square metre and topography classes. Standard errors shown.

No significant difference was found in capsule load of *E. globulus* among the topography classes ($H_4 = 3.61$, $P = 0.46$; Figure 39).

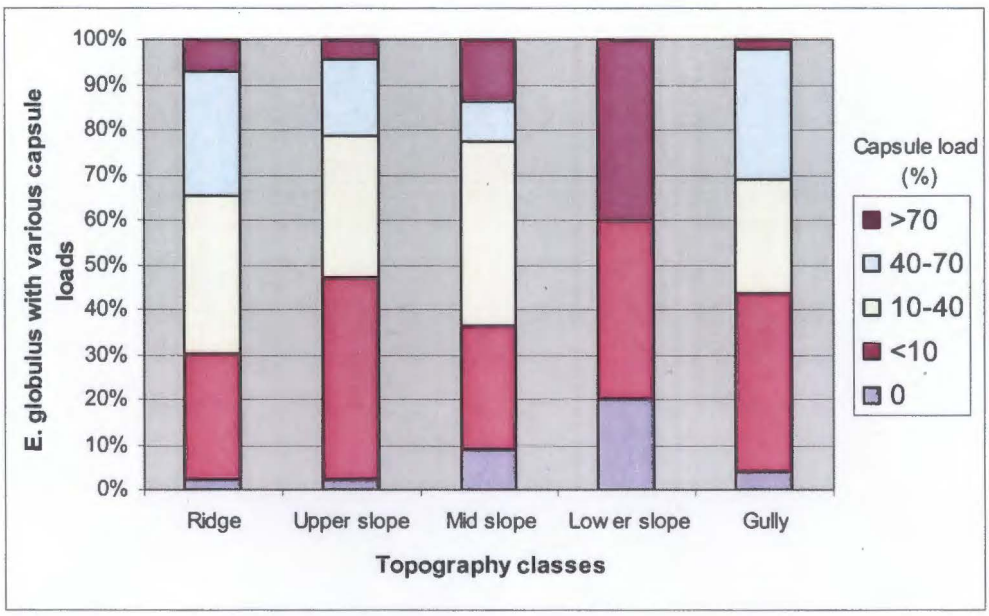


Figure 39. Comparison of *E. globulus* capsule loads and topography classes.

However, there was a statistically significant difference in the various capsule loads of *E. ovata* among topography classes ($H_3 = 9.19$, $P = 0.027$; Figure 40). Post hoc pair-wise tests revealed that there was a significant difference in capsule load between *E. ovata* on the ridge top and in a gully ($P = 0.0041$; $\alpha = 0.008$ after Bonferroni adjustment); whereby trees on the ridge top were likely to carry much heavier capsule loads than trees in gullies (Figure 40). The remaining differences between topography classes were non-significant (Figure 40). No *E. ovata* trees were recorded on the lower slope.

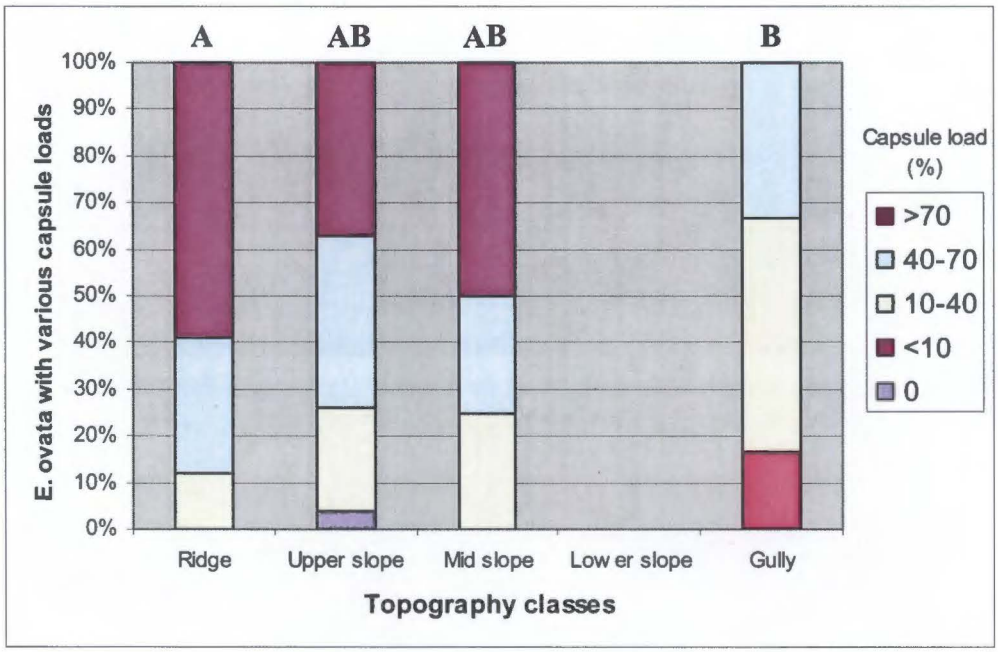


Figure 40. Comparison of *E. ovata* capsule loads and topography classes. Pair-wise differences between topography classes, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

3.4.4 Fire

There was a significant difference in the various levels of fire damage among the three contexts for *E. globulus* ($H_2 = 54.45$, $P < 0.001$; Figure 41). Post hoc pair-wise tests showed significant differences in fire damage between trees in the suburban and bush contexts ($P < 0.0001$), as well as suburban and edge contexts ($P = 0.0001$; $\alpha = 0.017$ after Bonferroni adjustment). The majority of suburban *E. globulus* (85%) showed no evidence of fire; whereas almost 80% of *E. globulus* trees in the bush carried some evidence of fire damage, with more than 17% recorded with a bridge or hollow in the tree base. Moreover, more than 63% of edge trees carried evidence of fire; whereby almost 11% of trees in that context had severe fire damage (Figure 41). No significant difference in fire damage was noted between edge and bush *E. globulus* ($P = 0.1$; Figure 41).

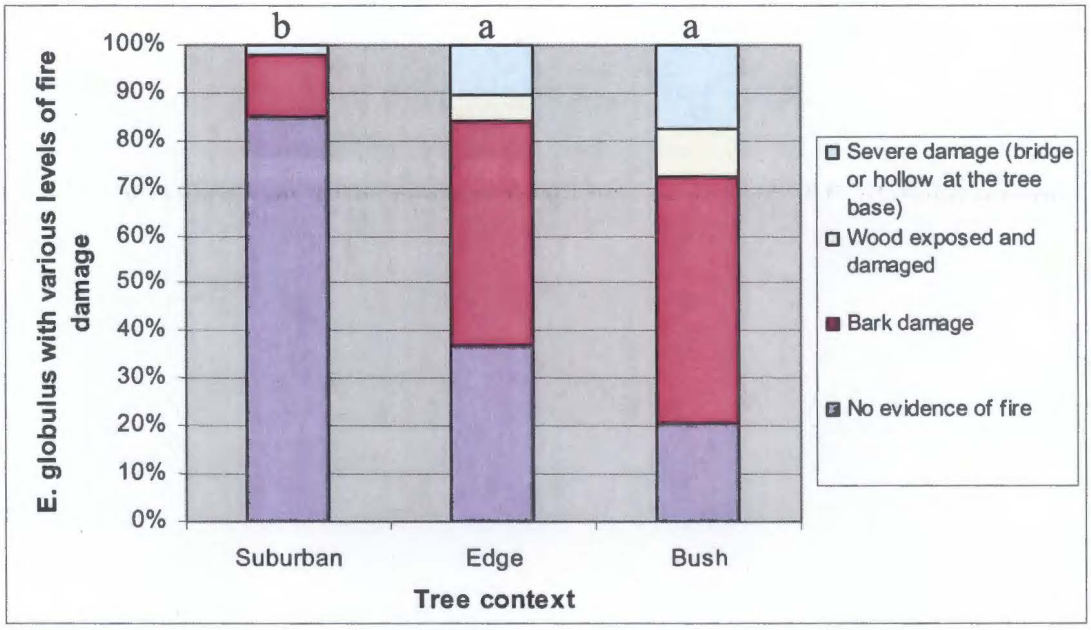


Figure 41. Comparison of *E. globulus* with various levels of fire damage in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

Similarly, a highly significant difference was found in the various levels of fire damage among the three contexts for *E. ovata* ($H_2 = 21.09$, $P < 0.001$; Figure 42). Post hoc pair-wise tests revealed that there were significant differences in fire damage for *E. ovata* between suburban and bush contexts ($P < 0.0001$), as well as between suburban and edge contexts ($P = 0.0013$; $\alpha = 0.017$ after Bonferroni adjustment). The majority of suburban *E. ovata* trees (95%) showed no evidence of fire; whereas 50% of edge and almost 64% of bush trees were recorded with some evidence of fire damage. The proportion of trees with severe fire damage was 33% for edge, and 36% for bush *E. ovata*. No trees with any form of wood damage caused by fire were recorded in the suburban context (Figure 42). No difference in fire damage was found for trees between edge and bush contexts ($P = 0.63$; Figure 42).

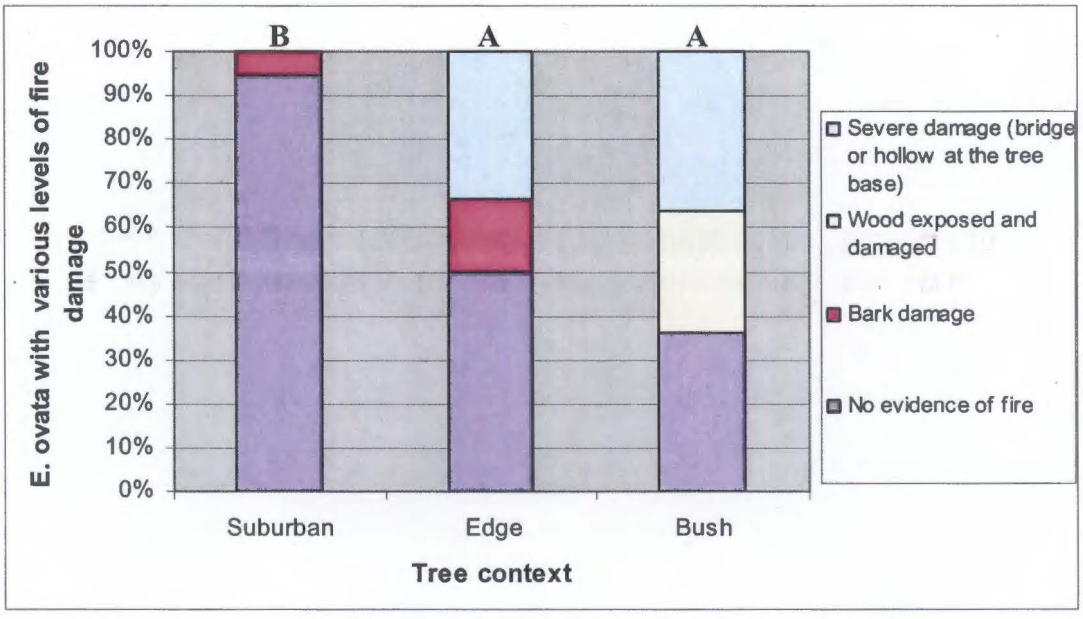


Figure 42. Comparison of *E. ovata* with various levels of fire damage in the three tree contexts. Pair-wise differences between contexts, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment).

A highly significant difference was found in the mean number of *E. globulus* opercula among the various classes of fire damage ($H_3 = 31.73$, $P < 0.001$; Figure 43). Post hoc pair-wise tests showed that the differences in opercula number were significant between trees with no fire damage and bark damage ($P < 0.0001$), trees with no fire damage and wood damage ($P = 0.001$), and trees with no fire damage and severe fire damage ($P = 0.0011$; $\alpha = 0.008$ after Bonferroni adjustment). The remaining differences in opercula number were non-significant (Figure 43). Figure 43 clearly indicates that the highest numbers of *E. globulus* opercula were observed in trees that did not suffer from any fire damage; whereas the numbers of opercula were much lower for trees showing some evidence of fire damage (bark damage, wood damage or severe fire damage).

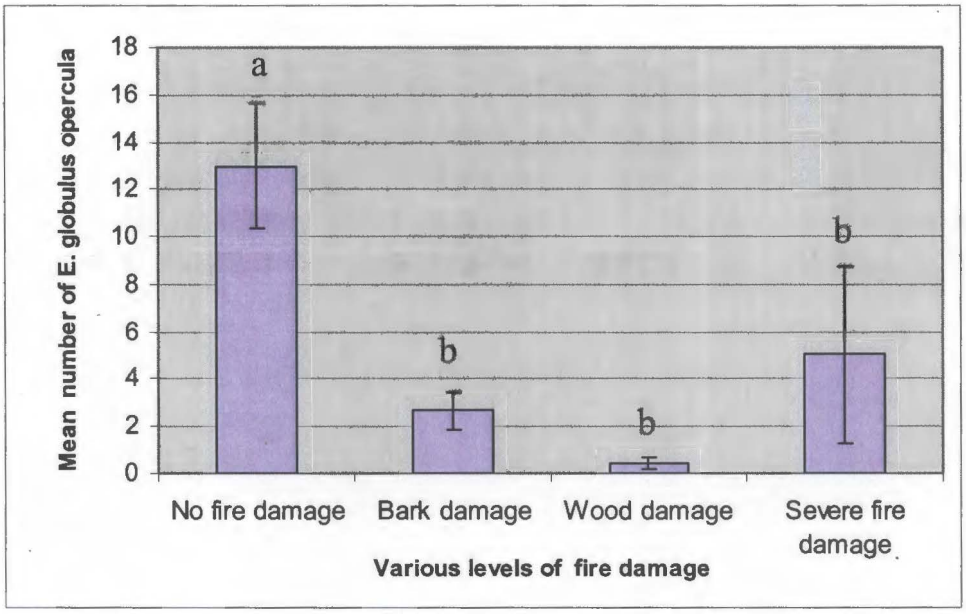


Figure 43. Comparison of *E. globulus* mean opercula number per square metre and various levels of fire damage. Standard errors shown. Pair-wise differences between various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

There was a significant difference in capsule load among the various classes of fire damage for *E. globulus* ($H_3 = 19.64$, $P < 0.001$; Figure 44). Post hoc pair-wise tests showed significant differences in capsule load between trees with no fire damage and bark damage ($P = 0.0001$), as well as trees with no evidence of fire and severe fire damage ($P = 0.0028$; $\alpha = 0.008$ after Bonferroni adjustment). The remaining differences between fire damage classes were not significant (Figure 44). Figure 44 indicates that the largest capsule loads were recorded in trees that did not show any evidence of fire occurrence. For *E. globulus* with fire damage, capsule loads were very similar among the three classes (bark damage, wood damage and severe fire damage), with at least a half of trees with < 10% capsule load.

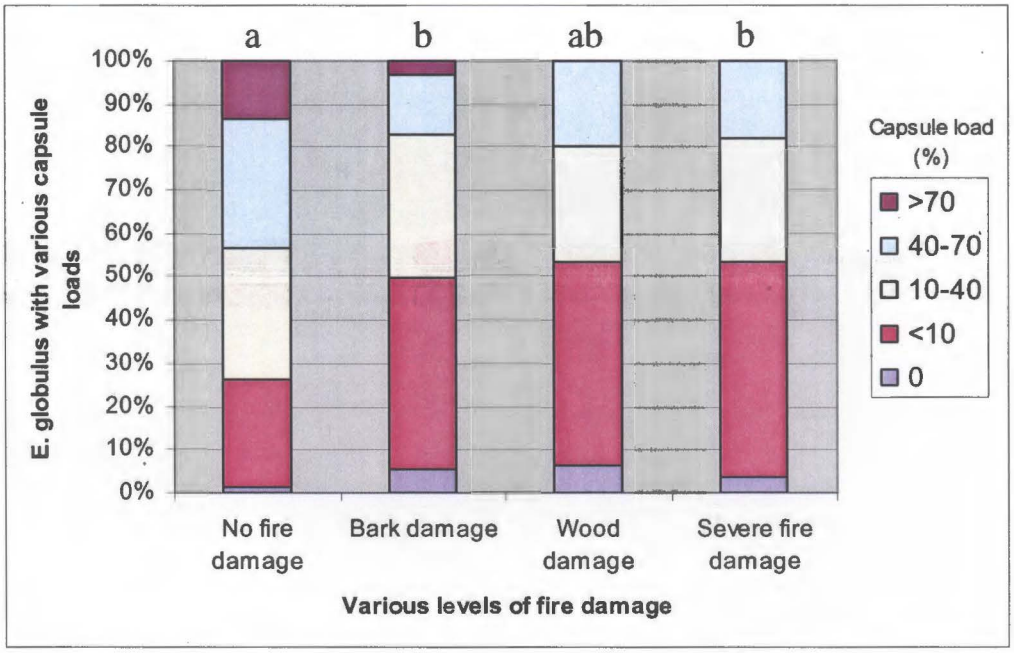


Figure 44. Comparison of *E. globulus* capsule loads and various levels of fire damage. Pair-wise differences between various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

There was also a significant difference in *E. ovata* capsule load among trees with various levels of fire damage ($H_3 = 11.62$, $P = 0.009$; Figure 45). Post hoc pair-wise tests showed a significant difference in capsule load between trees with no fire damage and severe fire damage ($P = 0.0078$). The differences between trees with no fire damage and wood damage ($P = 0.03$), and trees with wood damage and severe fire damage were non-significant ($P = 0.67$; $\alpha = 0.017$ after Bonferroni adjustment; Figure 45). Figure 45 shows that trees with no fire damage carried the largest capsule loads; whereby more than 52% of such trees were found with > 70% capsule load. No trees with capsule load of > 70% were recorded in the remaining three classes of fire damage. The majority of trees with severe fire damage or wood damage (67%) carried capsule loads of < 40%. Trees with bark damage were only recorded with 40-70% of capsules; however the number of trees in this class of fire damage was insufficient for valid pair-wise comparisons with other classes (Figure 45).

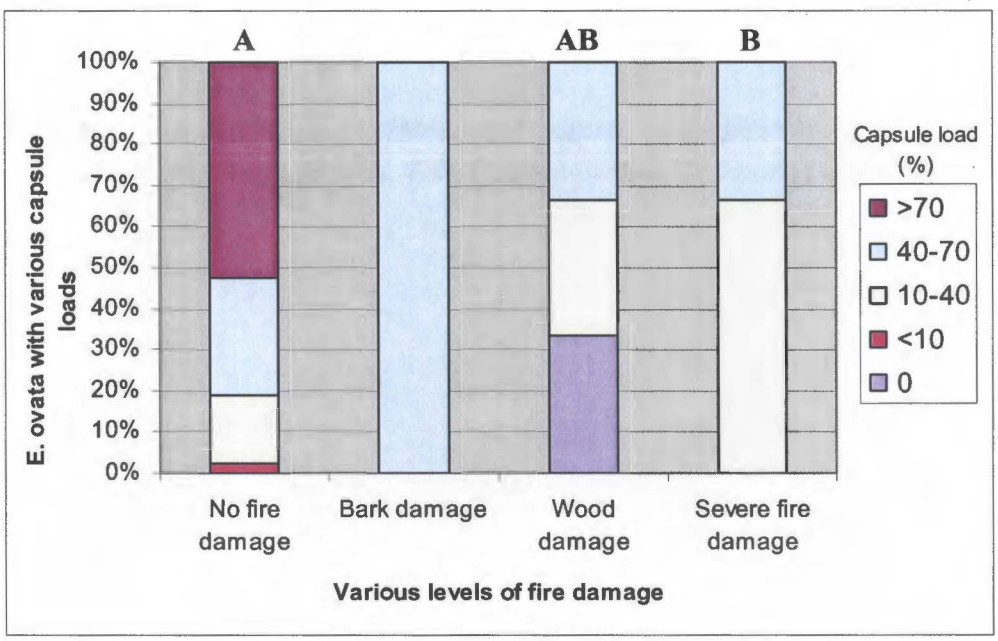


Figure 45. Comparison of *E. ovata* capsule loads and various levels of fire damage. Pair-wise differences between various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.017$, following Bonferroni adjustment). The 'bark damage' class was excluded from the post hoc tests due to insufficient data.

3.5 Fire impact on canopy density, tree dieback and the percentage of branches that were dead

3.5.1 Canopy density

There was a significant difference in the mean canopy density among *E. globulus* trees with various levels of fire damage ($H_3 = 9.16$, $P = 0.027$; Figure 46). Post hoc pair-wise tests revealed a significant difference between trees with bark damage and trees with wood damage ($P = 0.0044$; $\alpha = 0.008$ after Bonferroni adjustment); whereby the canopy of trees with bark damage was denser than that of trees with wood damage. The remaining differences between trees with various levels of fire damage were non-significant (Figure 46). The differences in canopy density among trees with various levels of fire damage for *E. ovata* did not show any significance ($H_3 = 1.81$, $P = 0.61$; Figure 46).

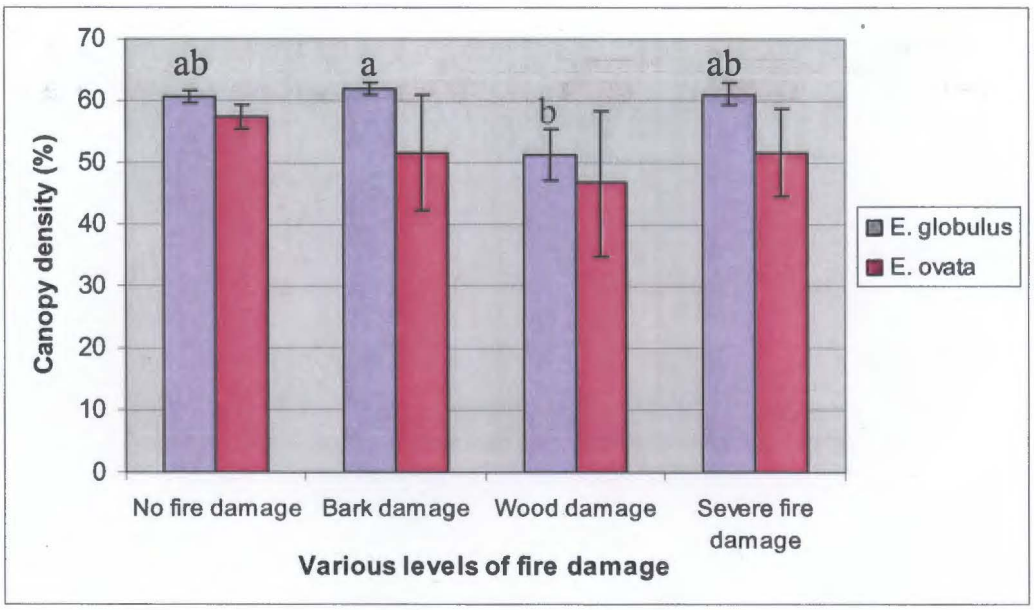


Figure 46. Comparison of the mean canopy density and various levels of fire damage for both *E. globulus* and *E. ovata*. Standard errors shown. Pair-wise differences between conspecifics with various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

3.5.2 Tree dieback

A significant difference was found in *E. globulus* dieback among trees with various levels of fire damage ($H_3 = 30.17$, $P < 0.001$; Figure 47). Post hoc pair-wise tests showed significant differences between trees with no fire damage and bark damage ($P = 0.0002$), trees with no fire damage and wood damage ($P = 0.0001$), and trees with no fire damage and severe fire damage ($P < 0.0001$). Trees with no fire damage comprised more healthy trees (76%) than did trees with bark damage (49%), wood damage (27%) or severe fire damage (25%) (Figure 47). The differences between trees with bark and wood damage ($P = 0.088$), trees with wood damage and severe fire damage ($P = 0.8$), and trees with bark damage and severe fire damage ($P = 0.048$) were all non-significant ($\alpha = 0.008$ after Bonferroni adjustment; Figure 47).

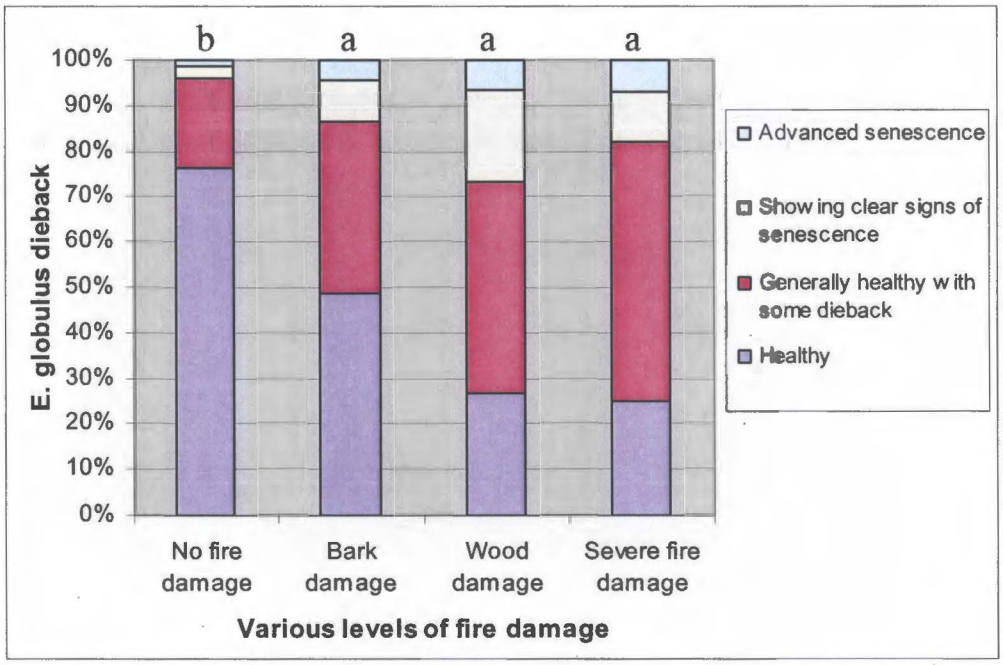


Figure 47. Comparison of *E. globulus* dieback and various levels of fire damage. Pair-wise differences between various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

For *E. ovata*, the difference in tree dieback among trees with various levels of fire damage was also significant ($H_3 = 11.29$, $P = 0.01$; Figure 48). However, post hoc pair-wise tests revealed a significant difference only between trees with no fire damage and severe fire damage ($P = 0.0036$; $\alpha = 0.008$ after Bonferroni adjustment; Figure 48). Almost 80% of trees with no fire damage were recorded as healthy; whereas the majority (67%) of trees with severe fire damage showed some signs of dieback (Figure 48). The remaining differences in dieback between trees with various levels of fire damage were non-significant (Figure 48).

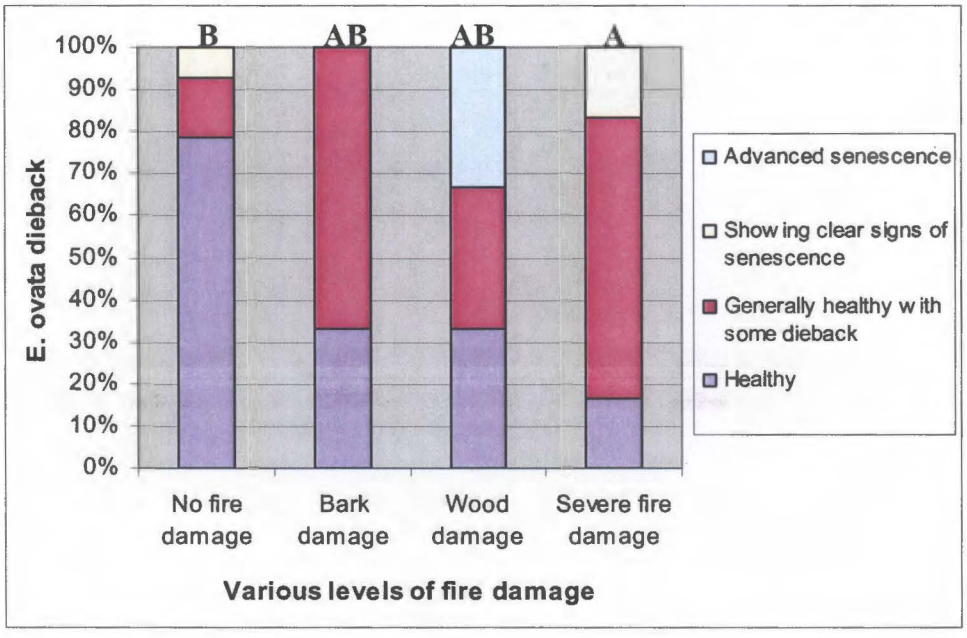


Figure 48. Comparison of *E. ovata* dieback and various levels of fire damage. Pair-wise differences between various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

3.5.3 The percentage of branches that were dead

There was a significant difference in the percentage of branches that were dead among *E. globulus* trees with various levels of fire damage ($H_3 = 18.81$, $P < 0.001$; Figure 49). Post hoc pair-wise tests showed significant differences between trees with no fire damage and bark damage ($P = 0.0013$), trees with no fire damage and wood damage ($P = 0.0009$), and trees with no fire damage and severe

fire damage (P = 0.0024); whereby trees with no fire damage were recorded with the smallest proportion of branches in the canopy that were dead. The lowest percentage of branches that were dead (0-5%) was observed in 67% of *E. globulus* with no fire damage, followed by 39% of trees with bark damage, 32% of trees with severe fire damage and 20% of trees with wood damage (Figure 49). There were no significant differences between trees with bark and wood damage (P = 0.087), trees with wood damage and severe fire damage (P = 0.39), and trees with bark damage and severe fire damage (P = 0.38; $\alpha = 0.008$ after Bonferroni adjustment; Figure 49).

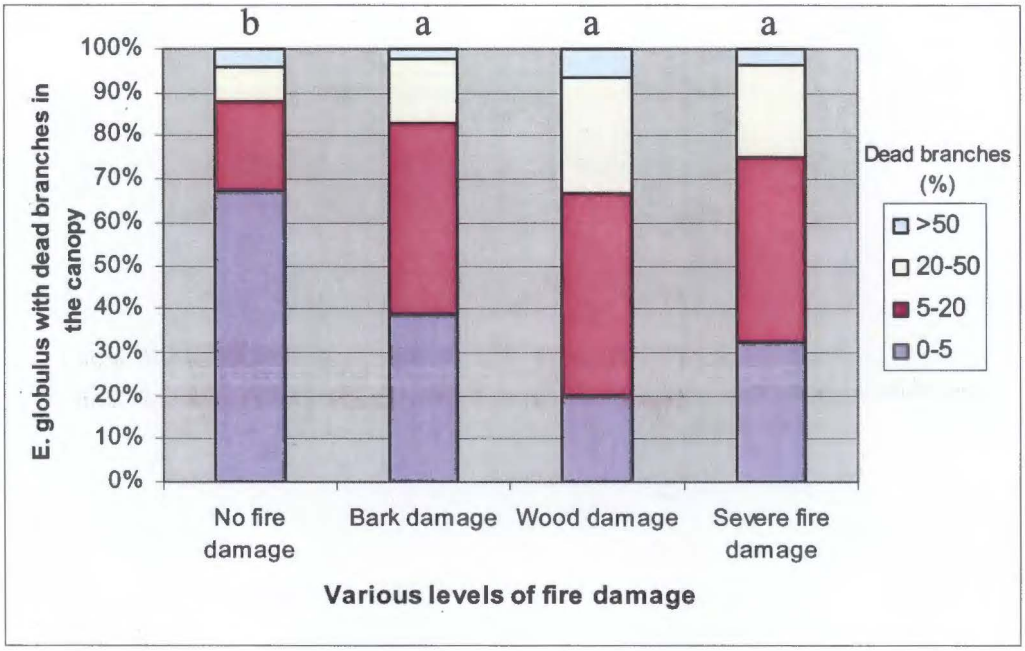


Figure 49. Comparison of *E. globulus* with various percentages of branches in the canopy that were dead and various levels of fire damage. Pair-wise differences between various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

A significant difference was found in the percentage of branches in the canopy that were dead among trees with various levels of fire damage for *E. ovata* ($H_3 = 16.4$, P = 0.001; Figure 50). Post hoc pair-wise tests revealed that the only significant difference in the percentage of branches that were dead was between trees with no fire damage and severe fire damage (P = 0.0004; $\alpha = 0.008$ after Bonferroni adjustment); whereby the proportion of dead branches in trees with no fire damage

was much lower than trees with severe fire damage. The lowest percentage of branches that were dead (0-5%) was observed in 79% of *E. ovata* with no fire damage, followed by 33% of trees with bark and wood damage, and 17% of trees with severe fire damage. Also, no trees with more than 20% of branches dead were recorded in the classes of no fire damage and bark damage; whilst 66% of trees with wood damage and 50% of trees with severe fire damage had more than 20% of branches in the canopy dead (Figure 50). The remaining differences in the percentage of branches that were dead between *E. ovata* trees with various levels of fire damage were non-significant (Figure 50).

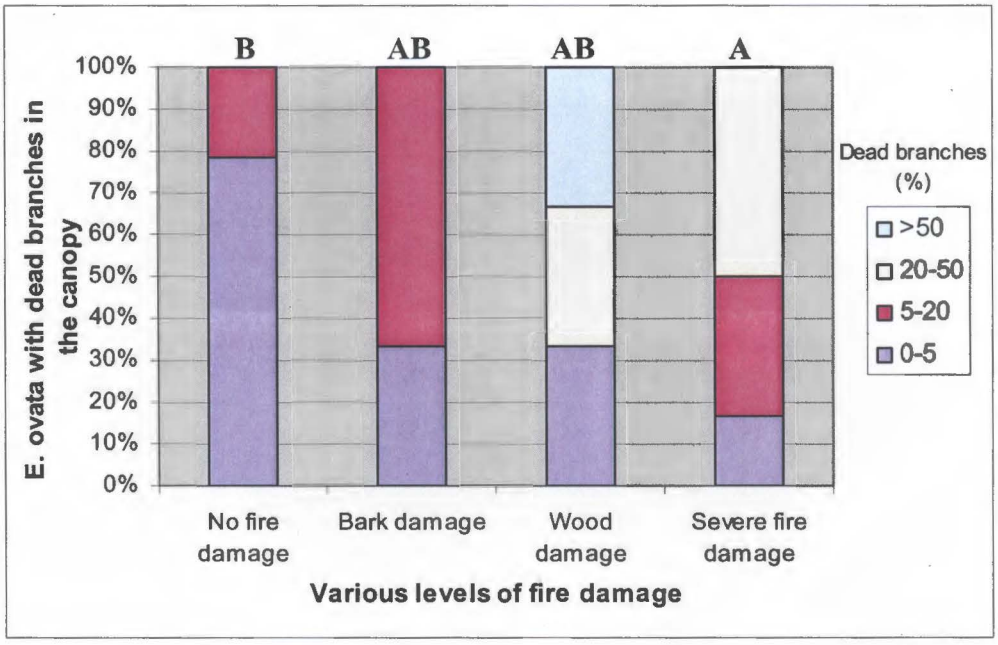


Figure 50. Comparison of *E. ovata* with various percentages of branches in the canopy that were dead and various levels of fire damage. Pair-wise differences between various levels of fire damage, as determined by Mann-Whitney U-tests, denoted by different letters ($\alpha = 0.008$, following Bonferroni adjustment).

3.6 Questionnaire

Two hundred and ninety-four responses were received after blank returns had been discarded. This represented a return of 35% of the 830 questionnaires originally dispatched. The majority of respondents (95%) were the owners of a Mount Nelson

property, and only 5% were renting. It is likely that respondents who were renting might not have had a full knowledge of the past and future state of vegetation on the rental property. However, since the number of those respondents was relatively low, their answers were included in the overall results.

3.6.1 Current state

Forty-nine per cent of the 294 residents declared to have large eucalypt trees on their property; whereas 51% said they had none. When asked about the current presence of large *E. globulus* and *E. ovata* on their property, 55% of residents (who claimed having large eucalypt trees) said that *E. globulus* was present; whereas 21% stated the occurrence of *E. ovata* (Table 2).

Table 2. Current presence of *E. globulus* and *E. ovata* on Mount Nelson properties, as well as past and future removal of both species.

	E. globulus		*E. ovata*	
	% of households	**Total # of households**	**% of households**	**Total # of households**
CURRENT STATE				
Present	55	79	21	31
Absent	26	37	44	63
Unsure if species present	19	28	35	50
		Total: 144*		**Total:** 144*
PAST REMOVAL				
Removed	35	40	14	16
Not removed	31	35	49	55
Unsure if species removed	34	38	37	42
		Total: 113**		**Total:** 113**
FUTURE REMOVAL				
Will remove	22	10	20	9
Will not remove	52	24	52	24
Unsure if species to be removed	26	12	28	13
		Total: 46***		**Total:** 46***

* Households with large eucalypts present (49% of 294)

** Households with large eucalypts removed in the past (38% of 294)

*** Households with large eucalypts to be removed in the future (16% of 294)

Of the 79 respondents who said they had large *E. globulus* on their property, 33 (42%) said they had only one tree, 18 (23%) had two trees and 9 (11%) had three *E. globulus*. There were only 19 (24%) properties with more than three *E. globulus* trees (Figure 51). Twelve (39%) properties were found to have one *E. ovata* present; whereas ten (32%) had two trees of that species. Properties with more than two *E. ovata* trees were rather scarce (9) and constituted 29% of the total of 31 properties with large *E. ovata* (Figure 51). The total number of large *E. globulus* occurring on 79 properties (declared as properties with *E. globulus* present) is estimated to be 263; whereas for *E. ovata* the number is 109 (based on 31 properties with *E. ovata* present). These are probably underestimates because, of the respondents who stated that they had large eucalypts on their property, 19% were unsure if they had *E. globulus* and 35% were unsure if they had *E. ovata* (Table 2)

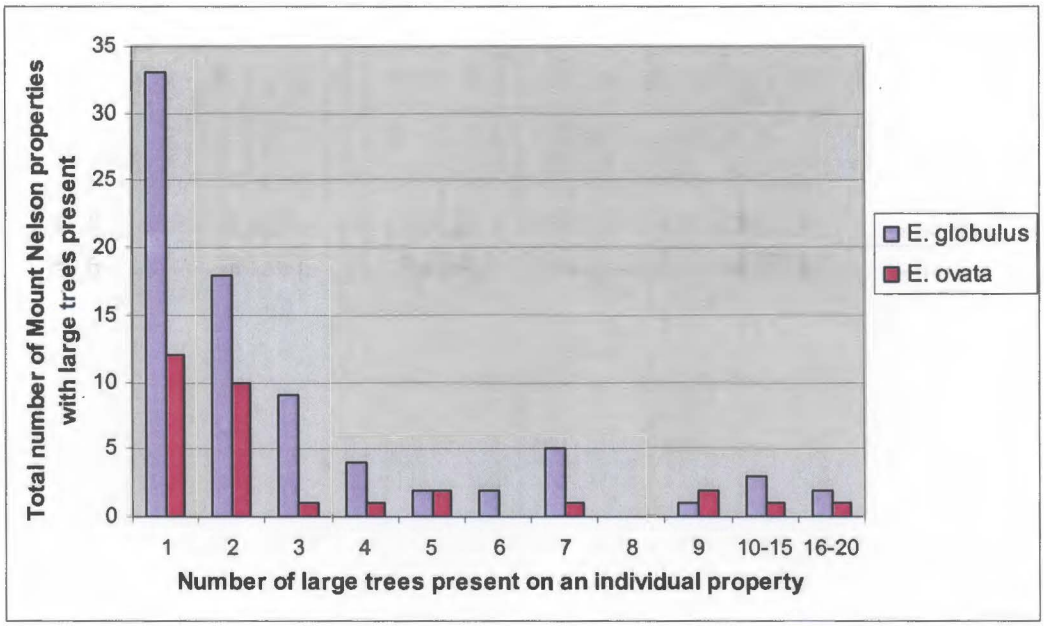


Figure 51. Comparison between the total number of Mount Nelson properties with large *E. globulus* and *E. ovata* occurring, and the number of large *E. globulus* and *E. ovata* present on an individual property.

3.6.2 Past tree removal

The majority of the 294 respondents (57%) said they had no large trees removed in the past five to ten years; whereas 38% stated that they had some trees felled in this period. A small percentage of people (5%) were not sure whether tree

removal had occurred in the past due to the fact that they were either renting the property or had not lived on the property for long enough.

Among the 113 respondents who confirmed that they had large eucalypts removed from their properties, 35% said that they had *E. globulus* felled; whereas 14% said they had *E. ovata* removed (Table 2). Twenty six (23%) residents claimed that they had just one *E. globulus* removed in the past five to ten years; whereas 9 (8%) had only one *E. ovata* cut down (Figure 52). The number of properties with more than one large tree felled is rather low and constitutes 14 (12%) for *E. globulus* and 7 (6%) for *E. ovata* (Figure 52). The total number of large eucalypt trees removed from the 294 Mount Nelson private properties suggests that more *E. globulus* than *E. ovata* have been cut down in the past five to ten years. About 88 *E. globulus* (25.1% of the trees present five to ten years ago) and 25 *E. ovata* trees (18.7% of the trees present five to ten years ago) in total have been removed from the 294 Mount Nelson properties according to the survey. However, there was no significant preference for removal of one species over another ($\chi^2 = 1.7$, $P > 0.1$). It is likely that greater numbers of trees of these species have been removed because, of the respondents who stated that they had removed large eucalypts, 34% were unsure if this included *E. globulus* and 37% were unsure if this included *E. ovata* (Table 2).

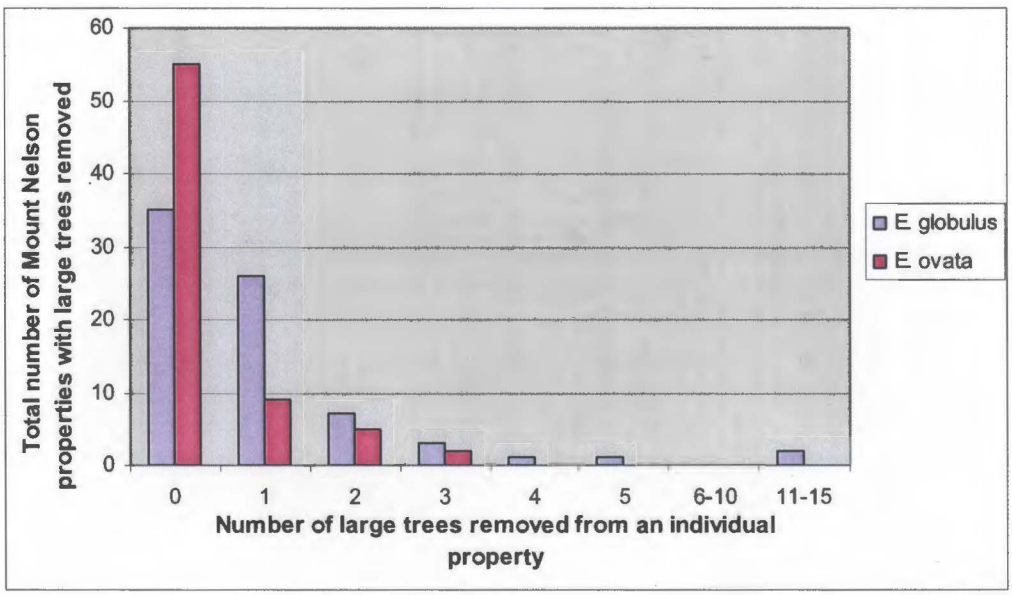


Figure 52. Comparison between the total number of Mount Nelson properties with large *E. globulus* and *E. ovata* removed, and the number of large *E. globulus* and *E. ovata* trees removed from an individual property in the past five to ten years.

3.6.3 Future tree removal

Seventy-three per cent of all respondents (294) declared that they had no intention of removing any eucalypt trees from their properties in the future, 16% said that they were planning on some tree-felling, and 11% were not sure whether tree felling will occur in the future.

Within the group of 46 residents who declared future tree removal, more than half said there would not be any *E. globulus* or *E. ovata* among the trees to be felled (Table 2). Only a small percentage of respondents confirmed a removal of *E. globulus* (22%) and *E. ovata* (20%) (Table 2). No one claimed they would have more than three of either of the two species removed (Figure 53). The total number of trees to be removed from the 294 Mount Nelson private properties in the future is estimated to be 13 *E. globulus* and 15 *E. ovata*. Together with the numbers removed in the past five to ten years, this equates to removal of 101 *E. globulus* (28.8%) and 40 *E. ovata* (29.9%). No significant preference for future removal of one species over another was found ($\chi^2 = 0.038$, $P > 0.8$). It is likely that greater numbers of trees of these species will be removed because, of the respondents who stated that they would have large eucalypts removed, 26% were unsure if this would include *E. globulus* and 28% were unsure if this would include *E. ovata* (Table 2).

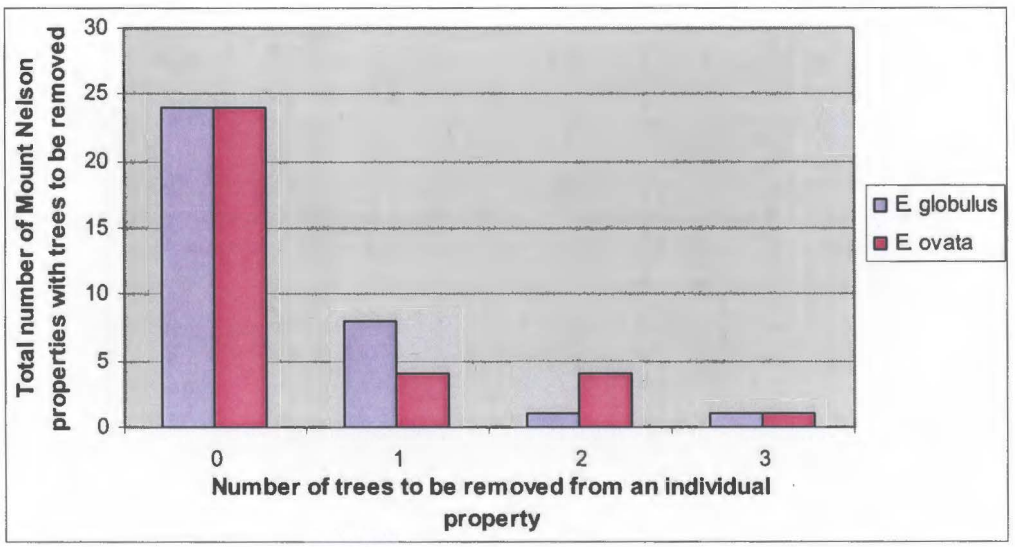


Figure 53. Comparison between the total number of Mount Nelson properties with trees to be removed, and the number of *E. globulus* and *E. ovata* to be removed from an individual property.

When asked about the reasons for tree removal, some respondents did not answer the question and some gave more than one answer; hence the numbers below reflect the frequency at which a particular reason was given. The most common reason (31 responses) for future tree removal was the anticipated house damage caused by falling limbs, as well as fire. Another rationale was the inconvenience that trees may cause (12 responses); such as cover the view, clog the gutters, make a mess, use too much water or spread roots. Tree sickness and its partial death or damage was also commonly given as a reason for removal (10 responses).

Question 12 from the questionnaire was not included in the analysis because of incomplete data received.

Chapter 4 - Discussion

4.1 Suburban and bush trees as foraging habitat for Swift Parrots

The findings of this study suggest that large suburban *E. globulus* and *E. ovata* produce more flowers than their edge or bush counterparts. The relationship between the capsule load and tree context was highly significant for both *E. globulus* and *E. ovata*, with large suburban trees carrying heavier capsule loads than their bush counterparts. This suggests a greater flower production in the suburbs over recent flowering seasons. There is, however, a possibility that low capsule counts in the bush are partly the result of poorer capsule retention, with losses of fruit likely to occur due to unusual climatic events, fire, disease or insect/fungal attacks (Ashton, 1975; Florence, 1996; Pook *et al*., 1997; Setterfield, 1997), in conjunction with progressive loss of capsules from beneath trees. The distribution of capsules underneath a tree can be distorted due to several factors, including a human impact (i.e. by raking, sweeping or disposing of litter from underneath a tree) as well as natural conditions of a particular tree context. For example, trees growing on a steep slope are likely to have their capsules wash down the slope with rain or slide down with gravity. Also, some ground covers (i.e. dense litter or large rocks) can greatly hinder a search for capsules due to reduced visibility and uneven terrain. In spite of these caveats, the opercula number of *E. globulus* was strongly related to the tree context and considerably higher in the suburbs than in the bush or edge contexts, which indicates that during the last flowering event (2007/08) large suburban *E. globulus* flowered more profusely than large bush or edge eucalypts of the same species. Moreover, large edge trees were recorded to have higher opercula numbers than large bush trees. This corresponds with the findings of Brereton (1997), who observed that edge trees tend to flower more prolifically than bush trees due to greater canopy of the former.

Greater flower production in large trees in the suburban context than in the bush suggests that the former provide more food resources to nectarivorous birds. If large suburban trees prove to consistently support a greater abundance of flowers when compared with large bush trees, then the amount of produced nectar and pollen by the former is also accordingly greater (assuming a comparable nectar and

pollen production per flower; although this assumption requires further research). Greater flower production of large suburban eucalypts would have a direct effect on a wide range of birds, for whom nectar and pollen are major dietary components, including the Swift Parrot. For example, a strong correlation between densities of many nectarivores, and nectar production or flowering intensity was observed by McGoldrick and Mac Nally (1998). It is thus argued that large suburban trees do not just provide a secondary (to bushland) food supply for Swift Parrots, but are likely to constitute an important foraging habitat in their own right outside bush areas. This supports the view of Ozolins *et al.* (2001, 201), who stated that the value of isolated trees is 'more important than their relative abundance' in the landscape. It is known that Swift Parrots often forage in gardens and parkland (Mallick *et al.*, 2004); however, further research looking at the use of suburban and bush trees as food sources by the Swift Parrot could contribute to the current knowledge.

4.2 The effect of structural and environmental tree variables on flowering

This study found that several structural and environmental variables were significantly related to both flowering intensity and context for each eucalypt species. They include canopy density, tree dieback, the percentage of branches in the canopy that were dead, and fire damage. The remaining structural and environmental variables, including tree height, tree basal area, Moisture Index based on aspect, ground slope and topography, did not seem to affect flowering intensity as much.

4.2.1 Canopy density

Canopy density showed a significant relationship with the capsule load for both *E. globulus* and *E. ovata* large trees; whereby denser canopies were more likely to carry heavier capsule loads. Also, there was a strong association between the opercula number and canopy density for large *E. globulus*, with higher numbers of opercula found under trees of higher canopy density. These findings suggest that denser canopies support a greater number of blossoms in both *E. globulus* and *E. ovata*, which could be a result of either a greater number of branches and twigs producing flowers, or more intense flower production per branch/twig, or both. This

relationship, however, requires more research.

Canopy density was also significantly related to the tree context for each of the eucalypt species; whereby the canopies of large trees in the bush context were found to be less dense than those of large trees in the suburban context. Hence, greater flowering in the suburbs than in the bush could be a direct result of the denser canopies in the former. A higher canopy density of the large suburban trees could be related to greater access to sunlight due to less competition with other trees; greater site productivity due to more nutrients (i.e. garden fertilisers or leaking sewage pipes); and greater water/moisture abundance (i.e. watering of private gardens, or runoff from paved surfaces and roofs). Water deficits at any stage of reproductive growth (i.e. bud initiation, anthesis, pollination, fruit and seed enlargement) are known to inhibit yield of fruits and seeds in trees (Kozlowski, 1982). However, due to time limitations, this project did not investigate either site productivity or water abundance, and their effects on flower production. Therefore, the preceding suggestions are speculative and could constitute an important area of future research.

4.2.2 Tree dieback and the percentage of branches that were dead

Tree dieback and the percentage of branches in the canopy that were dead were found to have a great impact on capsule loads for each eucalypt species and *E. globulus* opercula (except for the relationship between the percentage of branches that were dead and *E. globulus* capsule load), with large healthy trees with no or a low proportion of branches that were dead recorded with the highest numbers of opercula and capsules.

There was also a highly significant difference in tree dieback among the three contexts for each eucalypt species. Large suburban trees in Mount Nelson were much healthier than large bush trees, rarely showing dieback or signs of senescence. Similar results were obtained for the percentage of branches that were dead; whereby the majority (nearly 90%) of large suburban *E. globulus* and *E. ovata* was found with less than 5% of branches dead. Large trees in the two other contexts had many more branches in the canopy dead. Therefore, greater flowering in the suburbs than in the other two contexts could be a direct result of large trees in the suburbs showing less

signs of dieback or senescence, and having fewer branches that were dead. Better tree health in the suburban context could be explained by the fact that trees (in highly populated areas) with signs of old age, sickness or dieback are likely to pose a high safety risk to people and buildings (due to a higher rate of falling limbs or tree collapse); hence such trees are often prematurely removed (Gibbons and Lindenmayer, 2002; Section 3.6.3) or trimmed. Also, more frequent fire occurrence in the bush, as opposed to the suburban context, is likely to contribute to more dieback and a greater percentage of dead branches in the former.

4.2.3 Fire

Fire appears to significantly reduce flower abundance, as a strong negative relationship between fire damage and the number of *E. globulus* opercula was found. The greatest opercula numbers were recorded for large trees that did not show any evidence of fire, which indicates that trees that have not been affected by fire produced the largest amount of flowers in the last flowering season (2007-08). The numbers of opercula were much lower in large trees with greater fire damage. Similarly, a significant relationship was found between fire damage and capsule loads for each eucalypt species; whereby the greatest capsule loads were observed in large trees with no fire damage. This corresponds with the findings of Setterfield (1997), who observed that different fire regimes significantly affected the density of mature capsules in *E. miniata* and *E. tetrodonta* in northern Australia, with the density of capsules being significantly greater in the unburnt regime than burnt regimes. Despite the fact that the effects of disturbance (including fire) on eucalypt flowering (intensity and frequency) still remain poorly understood (Law *et al.*, 2000a), fires of different intensities can result in various levels of canopy scorch and accordingly lead to a loss of buds, flowers and capsules (Setterfield, 1997; Law *et al.*, 2000a). In the study conducted by Law *et al.* (2000a) on the north coast of New South Wales, some eucalypts were observed to flower poorly in response to frequent low-intensity burns. Law *et al.* (2000a) also noted that some species of eucalypts returned to their normal flowering patterns 1-3 years after fire. The response of *E. globulus* and *E. ovata* flowering to fires of different intensity is unknown and more research is required. In general, however, hot burns can affect the tree canopy by reducing its area and causing a direct bud loss (Setterfield, 1997). According to

Reekie and Bazzaz (1987), poor flowering after intense fires could be explained by allocating the resources away from reproduction into tree growth and canopy maintenance. In cooler burns, on the other hand, higher densities of buds remain due to a lower level of canopy scorch (Setterfield, 1997); and fewer resources are diverted into vegetative growth, including canopy maintenance (Reekie and Bazzaz, 1987).

The obtained results also suggest that suburban areas of Mount Nelson have been less affected by fire in comparison with bush and edge contexts. Hence, greater flowering in the suburbs than in the other two contexts could be the result of less fire damage in the former. Not only can fire directly affect the production of flowers (by causing canopy scorch, and bud and flower loss), but it could also indirectly contribute to lower flowering intensity. This study has found that fire occurrence was related to tree dieback, the proportion of branches in the canopy that were dead and, to a lesser degree, canopy density. Large trees recorded with more severe fire damage had more signs of dieback or senescence, and a greater percentage of branches in the canopy dead; both of which consequently resulted in lower number of produced blossoms. Also, fire damage in large *E. globulus* was related to the reduction in canopy density.

The rare occurrence of fire in the suburban context of Mount Nelson can be partly explained by the fact that the whole suburb has been carefully managed against fire in order to decrease the likelihood of uncontrolled extensive wildfires. Within the suburb, it is the residential areas that have the highest priority in protection against fire; where large trees are protected from fire either directly or indirectly as structures nearby are protected. Introduced fire breaks, regular back-burning and promoting awareness among Mount Nelson residents are some of the undertaken precautionary actions (Hickie, 1998; Hobart City Council, 1998). Moreover, dense development assists in providing its own bushfire protection; whereby trees often removed from properties contribute to discontinuity of the remaining canopies, hence preventing fire from spreading across the suburban landscape (Resource Planning and Development Commission, 2003b).

4.2.4 Height and basal area

Tree height and basal area are unlikely to affect the amount of produced flowers since no relationship was observed between opercula number, and tree height and basal area for large *E. globulus*; or between the capsule load, and tree height and basal area for either eucalypt species. The lack of relationship between tree height and flowering intensity has not been supported here by any literature known to the author. However, the above findings for the relationship between tree basal area and the number of produced flowers correspond with those of Wilson and Bennett (1999), who found no significant difference in flowering intensity between various diameter classes of eucalypts in a Box and Ironbark forest in Victoria. On the contrary, Brereton *et al.* (2004), who examined *E. globulus* trees of a wide range of diameter sizes (10-180 cm DBHOB), discovered that larger tree diameters can promote more flowers. The study of Brereton *et al.* (2004) shows that the flowering intensity of *E. globulus* tends to increase with tree diameter up to 99 cm DBHOB; followed by a decline in flowering intensity for trees with > 100 cm DBHOB; however the value for trees from 140 to 159 cm DBHOB was relatively high. The findings of Brereton *et al.* (2004) contrast with the results obtained in the current study, which (the latter) did not find a significant relationship between the flowering intensity and diameter (TBA); although the range of measured diameters (60-201 cm DBHOB) was less than that of Brereton *et al.* (2004).

Although the relationship between diameter and flowering frequency was not measured in the current study, the literature suggests that larger trees (> 40cm DBHOB) sometimes flower more frequently than do medium-sized and small individuals (Law *et al.*, 2000a; Brereton *et al.*, 2004), which also determines food availability for wildlife. Nevertheless, the relationship between tree size and flowering frequency was not confirmed in the study conducted by Kennedy and Overs (2001). The periodicity of flowering can be affected by tree dominance as shown by Pook *et al.* (1997), who found that dominant canopies of *E. maculata* on the south coast of New South Wales produced flower buds more frequently than did subdominant trees.

In general, tree height *per se* appears to be of little importance as a variable that determines the choice of habitat trees by fauna (Inions, 1985; Loyn, 1985). Nevertheless, tree basal area is considered a significant factor in tree selection by animal species (Ashton, 1975; Stoneman *et al.*, 1997). Braithwaite *et al.* (1989, 44) observed a positive correlation between bird species richness and the tree basal area; whereby tree basal area 'reflects the importance of both productivity and the level of [...] maturity'. Larger, hence older, trees offer a greater reliability of food production (Traill, 1993; Brereton, 1996; Wilson and Bennett, 1999; Law *et al.*, 2000b; Tzaros, 2002; Kennedy and Tzaros, 2005); thus they are preferred as food sources by some species, including the Swift Parrot (Kennedy and Overs, 2001; Tzaros, 2002; Brereton *et al.*, 2004; Kennedy and Tzaros, 2005). *Eucalyptus globulus* and *E. ovata* were found to have significantly greater basal area in the suburbs than in the bush. Hence, they may be preferred by Swift Parrots for this reason, even if larger trees do not produce more flowers.

4.2.5 Slope and Moisture Index based on aspect

This study showed that slope angle had no significant effect on the amount of produced flowers by either large *E. globulus* or *E. ovata*, despite the fact that slope angle can affect the amount of received solar energy; whereby the amount of radiation received rises as the ground slope increases up to 30° on the north, north-westerly and north-easterly slopes (at the latitude 35° S) (Jacobs, 1955).

Moisture Index based on aspect also had little effect on the amount of blossoms produced by each species of eucalypt, since no significant difference was found between Moisture Index and capsule load for either large *E. globulus* or *E. ovata*. A close relation was found only between Moisture Index and *E. globulus* opercula numbers; whereby the opercula numbers were highest in locations that were facing north-west (the least moist; however with plenty of solar energy). Since large bush *E. globulus* were found on moister aspects than large trees in the edge or suburban contexts, with the highest percentage of trees on north-westerly aspects recorded in the suburban context, high opercula numbers on slopes facing north-west are likely to be related not as much to Moisture Index based on aspect, but tree context; with large suburban *E. globulus* producing more flowers. The alternative

explanation, that flowering is greater in the large suburban trees than large bush trees because the former occur more frequently on drier and sunnier aspects, seems less likely due to several reasons. Firstly, the numbers of capsules for each eucalypt species and *E. globulus* opercula were strongly related to the context; whereas only *E. globulus* opercula were affected by Moisture Index. Secondly, large suburban *E. globulus* had many more opercula than large edge trees of the same species, but the Moisture Index based on aspect of these two contexts was similar. Finally, the above results regarding aspect and ground slope support those of Law *et al.* (2000a), who found that the amount of solar radiation had little influence on flowering levels.

4.2.6 Topography

Flowering intensity of large *E. globulus* did not seem to be affected by topography. There was, however, a significant relationship between capsule load of large *E. ovata* and topography classes, indicating that trees higher on the slope and on the ridge top were likely to carry a greater number of capsules than those in gullies; hence produce more flowers. More data are required to support this relationship, especially for large trees from the lower topography classes (mid slope, lower slope and gully).

The findings obtained for *E. ovata* could be a direct result of the topographic differences between the three contexts; with suburban areas located mostly on the ridge top and higher on the slope, and a high percentage of bush trees found in gullies. This would indicate that the context, not topography, is the driving factor influencing the number of produced flowers. The alternative explanation, that flowering is greater in the large suburban trees than large bush trees because the former occur more frequently on the ridge top and upper slope of Mount Nelson hill, seems to be less likely due to several reasons. Firstly, as mentioned earlier, capsule loads for each eucalypt species and *E. globulus* opercula were strongly affected by context; however only *E. ovata* capsule load was related to topography. Secondly, large suburban *E. ovata* had much greater capsule loads than large edge trees; however the topography in these two contexts was similar. Also, the above findings support those of Law *et al.* (2000a), who conducted a study on 20 eucalypt species in New South Wales and examined the differences in flowering patterns between

different topographical locations (gully versus ridge). Law *et al.* (2000a) found that for the majority of species those differences were not discernible, which suggests that local site conditions are not a strong determinant on flowering levels.

4.3 Suburban and bush trees as nesting habitat for Swift Parrots

The preponderance of eucalypts showing signs of dieback or senescence and fire damage in the bush context of Mount Nelson is likely to have a direct effect on the distribution of tree hollows for Swift Parrot nesting.

Tree age is a good indicator of hollow occurrence (Lindenmayer *et al.*, 1993). As trees grow older, they become physiologically weak; which is associated with losing branches and being prone to physical injuries, and can consequently lead to decay exposure and hollow formation (Gibbons and Lindenmayer, 2002). The majority of eucalypts are known to develop hollows that are suitable for fauna at the age of 150-200 years old (Gibbons *et al.*, 2000), depending on the growth rate of the eucalypt species involved (Wormington and Lamb, 1999). Therefore, trees at an advanced stage of senescence are more likely to contain hollows, as opposed to young and healthy stems (Gibbons *et al.*, 2000). However, due to premature removal (i.e. for safety and other reasons; Section 3.6.3), suburban trees often do not become old enough to develop cavities suitable for nesting or roosting of wildlife. Apart from removal of older trees, pruning (i.e. safety reasons) also seems to be a common practice within the suburban context, as more branches that were dead were found in the edge context than suburbs. Pruning is likely to affect hollow occurrence because it can dramatically reduce the amount of large and hollow branches that tend to support most tree hollows (Gibbons and Lindenmayer, 2002). The findings of this study indicate that those large *E. globulus* and *E. ovata* trees that were most predisposed to contain hollows due to a high percentage of branches in the canopy dead were more likely to occur in the bush and, to a lesser extent, the edge than in the suburban context. This corresponds with the findings made by Shukologlou (2004, in Harper *et al.*, 2008, 245), who noted that urban development is likely to result in a paucity of hollow-bearing trees outside bush remnants across the broader urban landscape.

Fire history and the occurrence of fire scars are also good indicators of the likelihood of hollow occurrence (Taylor and Haseler, 1993), as fire is one of the major contributors to hollow development in trees (Lindenmayer *et al.*, 1993; Soderquist, 1999). Fire is known to predispose trees to form hollows at a higher rate (Inions *et al.*, 1989; Taylor and Haseler, 1993) through reducing the age at which trees produce hollows (Inions, 1985), as well as excavating the existing decay and increasing the rate of branch shedding (Gibbons and Lindenmayer, 2002). In effect, fire-damaged trees tend to have a greater number of hollows (Taylor and Haseler, 1993). Hence, the observed scarcity of fire damage in suburban trees also suggest that large bush and edge trees of Mount Nelson are more likely to support a greater number of hollows than large suburban trees. Mount Nelson bushland has been subjected to some dramatic fire events that most likely contributed to hollow formation within the area (Sutton, 1985; Hickie, 1998; Hobart City Council, 1998). Particularly severe were the fires of 1967 that engulfed much of the bushland of Mount Nelson. Much damage was done to vegetation on western and northern aspects (Sutton. 1985; Hickie, 1998). In 1982, another fire broke out and spread across almost the entire area of the Skyline Reserve (now part of Bicentennial Park) (Sutton, 1985). In 1995, fire burnt a part of the slope below Bend 6 and University Reserve (Hobart City Council, 1998); in 1998, fire engulfed the bush of Hobart College and University Reserve; and in 2006, part of University Reserve was burnt (A. Hingston, pers. comm.).

4.4 Loss of important habitat through tree removal

Tree removal started in Mount Nelson prior to the suburban development and continued after the development commenced in the 1940s (Elton *et al.*, 1997). Despite more than 60 years of urban sprawl, Mount Nelson is still considered to be a 'green' suburb within the greater Hobart. It is not just the surrounding bush that provides the 'leafy feeling' to the area, but also numerous scattered eucalypt trees found along roads, around public facilities and on private properties.

Tree cutting, however, still occurs today, as the suburb grows and subdivisions continue. As a result, the integrity and continuity of the native suburban vegetation is threatened. The total numbers of large trees removed in the past five to

ten years and large trees to be removed in future equate to the loss of 101 *E. globulus* (28.8%) and 40 *E. ovata* (29.9%) within 294 Mount Nelson properties. This is equivalent to removal of nearly one third of large trees of each eucalypt species. Nevertheless, considering the fact that the majority of the residents (64%) targeted in this study did not respond to the questionnaire, the total numbers of large trees removed from Mount Nelson in the past five to ten years, as well as large trees to be removed in the future remain unknown. Moreover, the results of the questionnaire should be viewed with caution as the identification of *E. globulus* and *E. ovata* by Mount Nelson residents might have not been accurate. However, judging by the number of tree-cutting activities in the area (author's pers. obs.), it can be presumed that the numbers of trees being removed are likely to be high.

The ongoing development (subdivisions) within the suburb will, without a doubt, lead to further tree loss, especially on private land as the protective prescriptions do not apply to the privately owned estates. Within residential gardens, as housing density increases, spatial considerations are likely to result in increasing numbers of smaller garden plants (including exotic species) at the expense of large eucalypt trees (Harper *et al.*, 2008). Trees on private properties in Mount Nelson are also felled due to several other reasons. According to the survey, the most common reason trees are felled is associated with risks to human safety caused by large eucalypts (i.e. fire hazard, falling limbs, etc.). A similar observation was made by Mallick *et al.* (2004), who found that safety reasons are mainly responsible for removal of suburban trees, especially when trees reach a large size. However, this study has also found that 'inconvenience' caused by eucalypt trees (i.e. lack of view, sunlight blockage, falling leaves and capsules, clogged gutters, increased water consumption, etc.) was also named as a justification for tree removal. In addition, Webb and Foley (1996) noted that landowners in Sydney, New South Wales, often encroach onto adjacent bushland to remove trees for views or extension of private gardens; thereby contributing to diminution of the neighbouring native bush.

Landsat satellite remote sensing data from 1994 to 1999 revealed an increasing fragmentation of vegetation for the greater Hobart area, which in Mount Nelson was due to clearance of woody vegetation for new housing development (Resource Planning and Development Commission, 2003a). It is estimated that between 1992

and 2002 housing completions affected 805 ha of priority forest vegetation in the greater Hobart area (Resource Planning and Development Commission, 2003c). With further expansion of the fringing settlement in Mount Nelson, pressure on retention of the existing environmental values will become more evident (Hickie, 1998). A further loss of suburban trees can result in an incremental loss of an important fauna habitat and severely reduce the degree to which the larger patches of native bush are connected. This would lead to an increased habitat fragmentation and potentially affect those species that utilise the habitat provided by scattered trees for foraging, nesting, roosting or to move across the landscape. This could reduce viability of populations of some species. For example, a continuous attrition of *E. globulus* and *E. ovata* (whether it is in the suburban or bush areas of Mount Nelson) is likely to result in a further reduction in habitat quality for nectarivorous birds, such as the Swift Parrot, through diminished reliability of nectar and pollen resources (Swift Parrot Recovery Team, 2001).

4.5 Management implications for the maintenance of Swift Parrot habitat

The aim of conservation management is to provide for continued survival of the biota. In a patchy or heterogeneous environment, such as a suburban landscape, it involves preventing local patch extinctions from becoming landscape, regional or sub-continental extinctions (Merriam, 1991). Conserving and restoring urban biodiversity requires understanding and predicting 'species–habitat relationships at multiple ecological levels and [determining] the relative importance of the amount of habitat, its spatial configuration and its condition on species survival' (Garden *et al.*, 2006, 127).

As mentioned in Section 1.2, the habitat of the Swift Parrot is highly fragmented and declining (Brereton, 1996; Swift Parrot Recovery Team, 2001), and the population size is already alarmingly small (Garnett and Crowley, 2000; Swift Parrot Recovery Team, 2001; Saunders *et al.*, 2007). Therefore, in order to save the population of the endangered species, conservation management including habitat retention and conservation is urgently required (Kennedy and Tzaros, 2005).

Despite the fact that bush eucalypts are likely to contain more hollows suitable for fauna than suburban trees (Section 4.3), the current study showed that large bush trees flower less intensely than large suburban eucalypts; thus the former are likely to constitute a less reliable nectar and pollen source for the Swift Parrot. Therefore, bushland preservation alone does not ensure retention of foraging habitat in Mount Nelson for the Swift Parrot. It is argued in this paper that the ecological values of the existing bushland reserves in Mount Nelson (i.e. long term viability of native species) can be supported and enhanced by the surrounding suburban vegetation. Bennett and Ford (1997, 244) suggest that the occurrence of birds in a bush fragment 'is not simply a function of the internal dynamics of that fragment, but is dependent on its context in the landscape and the nature and amount of habitat in the surrounding landscape'. In Mount Nelson, a large part of that 'suburban' habitat (including isolated trees and small bush patches) is located on private, unprotected land. North (2000) listed a number of small suburban bush patches on private land that, despite their fragmented nature, support significant remnant plant communities and rare species. Acquisition of the privately-owned areas into public land and appropriate planning preventing land clearance could maintain the existing biological values of all of the scattered bush areas outside larger remnants (North, 2000). Indeed, long term conservation of the Swift Parrot and its ultimate survival should focus on retention and conservation of not only *E. globulus*- and *E. ovata*- dominated forests and woodlands (Brereton, 1997), but also small remnant patches and scattered trees (Brereton *et al.* 2004). The latter includes retention and planting of *E. globulus* and *E. ovata* in the suburban areas since the Swift Parrot is a common user of isolated suburban trees (Brereton, 1997; Brereton *et al.*, 2004; Mallick *et al.*, 2004) and small remnant tree stands (Brereton, 1996). This could also benefit other fauna species using such trees either as foraging or nesting/roosting habitats, or as conduits allowing movements through the suburban landscape. For example, Hingston and Potts (1998; 2005), and Hingston *et al.* (2004) recorded a wide variety of birds feeding from flowers of *E. globulus* trees.

Retention and spatial distribution of large eucalypts should be well planned as it can be critical for the native fauna and could enhance their environment. Knowing the localities of the large eucalypt trees (especially when they are visited by wildlife

on a regular basis) is very important for conservation purposes (Brereton, 1996), as it can assist in retention of prime habitat. In general, selection of large habitat trees for retention should be based on their ability to provide nectar, seeds and hollows (Gibbons and Lindenmayer, 2002). Retention of the existing large trees, as well as tree plantings (including a replacement of dead or sick trees) could ensure a continuing supply of foraging and nesting sites for fauna species, including Swift Parrots (Brereton *et al.*, 2004). Trees that have not been used as foraging trees by Swift Parrots may support the species in the future (Brereton, 1997); hence should be considered as potentially valuable. Retention and recruitment of trees of smaller diameter should also occur and be kept at a level that ensures long-term ecological sustainability (Harper *et al.*, 2005), whereby 'recruitment exceeds attrition in the > 60 cm DBHOB size class' (Kennedy and Tzaros, 2005, 171). However, based on a study conducted by Gibbons *et al.* (2008) on scattered trees in agricultural landscape in several countries (including Australia), it can be anticipated that similarly to the paddock trees with reduced diversity of age classes, the replacement of mature scattered trees with new recruits in suburban landscapes would take considerably longer than the period before these mature trees are removed due to safety issues. It is thus expected that mature scattered trees will continue to decline until the firstly-planted recruits reach maturity, which needs to be followed by regular recruitment events 'at a frequency in years equivalent to around 15% of the life expectancy of the trees' (Gibbons *et al.*, 2008, 1317).

Continued tree felling renders suburban large eucalypts under increasing threat and in need of urgent attention. All existing vegetated areas including isolated trees with perceived conservation values need to be managed for nature conservation, regardless of ownership. In the face of the current uncontrolled tree removal (especially from private properties) resulting in a decline in eucalypt numbers in suburban Mount Nelson, there is a need for more effective management actions. The future availability of large trees will be directly amenable to such actions (Bennett *et al.*, 1994).

There is a strong need for management prescriptions and implementation of environmental laws protecting native vegetation, including large eucalypt trees, especially on private land. There are no controls under the *Forest Practices Act*

1985 on clearing of non-forest vegetation that is not threatened on both private and public land in Tasmania. Despite the fact that some controls apply to clearing of threatened non-forest native vegetation (as listed in the *Nature Conservation Act 2002*), exemptions can be made, for example, for clearing that is necessary to protect the existing infrastructure (i.e. dwellings, fences) or for public safety. Moreover, small scale clearing up to one hectare per property per year can also be allowed, providing it involves less than 100 tonnes of timber and it does not occur on vulnerable land (Forest Practices Authority, 2007).

There have been a couple of useful tools and practices that the local government applied in the nearby suburb of Tolmans Hill before and during the process of subdivision, in order to preserve native bushland and its values. For example, tree surveys were required to properly assess the further tree loss at the sealing stage of a subdivision. Also, lot size was used to control the removal of vegetation, with larger lots having the potential to be more effective in protecting the bushland values than smaller lots. What is more, according to a principle of bushland development, 50% or more of the native vegetation had to be retained for each residential lot as per local area plans (Resource Planning and Development Commission, 2003b). Such prescriptions of tree retention within new subdivisions could assist in ensuring foraging habitat for the Swift Parrot in the suburban context.

However, regardless of introduced regulations, the level of protection of native vegetation on private land seems to be strongly dependent on the attitudes and practices of the property owners (Resource Planning and Development Commission, 2003b). Therefore, effective education programs and communication are required to raise awareness of the ecological values of the bushland and scattered suburban trees, as well as the benefits of native wildlife. The management should encourage public participation in taking pride and care of the suburban native vegetation (Low, 1991). Ways should be found to encourage community involvement in the conservation and management of the native flora and fauna of Mount Nelson. For example, strong participation in activities supported by volunteering groups, such as Mount Nelson Bushcare, could aid the adoption of relevant conservation practices and raise awareness of the significance of native vegetation in maintaining and preserving the native fauna of Mount Nelson. Moreover, Lawson *et al.* (2008) noted that

allocating more resources into conservation of urban vegetation can not only protect threatened, isolated populations of species, but also contribute to building social interest in conservation. Also, 'enhancement of biodiversity in urban ecosystems can have a positive impact on the quality of life and education of urban dwellers and thus facilitate the preservation of biodiversity in natural ecosystems' (Savard *et al.*, 2000, 131).

Finally, since fire was found to be related to flowering intensity of both eucalypt species, appropriate fire management in the bush focused on preventing canopy scorch could possibly enhance the foraging habitat for Swift Parrots. As mentioned earlier (Section 4.2.3), hot burns can cause canopy scorch and a direct bud loss in eucalypts; whereas cooler burns do not affect the canopy as much (Setterfield, 1997). Currently, prescribed low intensity burning occurs only in Bicentennial Park (Hobart City Council, 1998). However, in University Reserve, Hobart College bush and Truganini Conservation Area there is no active fire management (A. Hingston, pers. comm.); hence fires there are less frequent, yet more intense, often causing severe canopy damage and potentially reducing flowering intensity. Therefore, there is a strong need for more research and introduced fire management plans for these reserves, with a focus on low intensity burns.

Chapter 5 - Conclusion

The findings of this study demonstrate that both large *E. globulus* and *E. ovata* trees in Mount Nelson are more likely to produce a greater abundance of flowers in the suburban context than edge or bush. Despite seasonal fluctuations of eucalypt flowering, large suburban trees are predisposed to provide a more reliable source of nectar and pollen for a range of nectarivorous species, such as the endangered Swift Parrot, than are large bush trees. Therefore, large suburban trees are likely to constitute not just a secondary foraging source for the Swift Parrot, but comprise a very important habitat in their own right outside the existing bush remnants.

Denser tree canopies, common in the suburban context, were more likely to carry a greater number of flowers than canopies of lesser density in the bush. The reasons for that relationship have not been investigated in this study; however it is speculated that greater canopy densities in the suburban context may be due to less competition with other trees and a greater access to sunlight, water and nutrients. Greater flower production could be a result of either larger numbers of branches supporting flowers, or more intense flower production per branch, or both.

Moreover, healthy trees with no or a low proportion of branches in the canopy that were dead were also more likely to produce a greater number of flowers and were mostly found within the suburban context. A greater percentage of healthy trees in the suburban context than bush is likely to be a direct result of removal of trees showing signs of dieback or senescence; or trimming of dead, large or hollow branches, mainly due to safety reasons.

Also, large trees recorded with no fire damage had greater capsule loads and opercula numbers than large trees with more severe fire damage. Hence, it can be argued that fire can impact on flower production of *E. globulus* and *E. ovata* by causing damage to the canopy and consequently resulting in loss of buds and flowers. However, fire can also have an indirect impact on the flowering intensity as it was strongly related to tree dieback and the percentage of branches in the canopy that were dead, and to a lesser degree canopy density of *E. globulus*. Large trees with

more severe fire damage were recorded with more signs of dieback or senescence, and a greater percentage of branches that were dead; all of which were associated with low numbers of produced flowers. While the majority of large suburban trees had no evidence of fire, the overall percentage of fire-damaged large eucalypts was the highest in the bush. This could be explained by safety measures undertaken in the suburban context of Mount Nelson to protect residential properties from fire damage; whereby suburban trees nearby the existing structures are also protected.

Based on the measured tree variables, including tree dieback, the percentage of branches in the canopy that were dead and fire occurrence, it is also anticipated that the likelihood of large suburban trees of Mount Nelson containing nesting hollows is rather low. On the contrary, hollow-bearing trees are more likely to occur in the bush context as they show more prominent fire damage, and signs of dieback or senescence, also associated with a larger proportion of branches in the canopy that were dead.

One of the major findings of this study is that the above characteristics of large suburban trees that were associated with greater flowering are likely to be typical not just of Mount Nelson, but also other suburban areas. Therefore, it can be presumed that the observed higher production of flowers in the suburbs is not a site-specific response caused by confounding factors of aspect and topography, but instead can be extrapolated to other areas. Hence, this study suggests that large eucalypt trees in the suburban context constitute a very important resource in providing nectar and pollen for birds, including the Swift Parrot.

The results of the survey conducted among Mount Nelson residents indicate that a great proportion of those large suburban scattered trees, including *E. globulus* and *E. ovata*, occurs on private land. What is more, the future of these suburban trees is under threat due to ongoing tree felling within the suburban context. The survey findings show that the number of large trees removed in the past five to ten years, together with trees yet to be felled in the near future equates to the removal of almost one third of large trees of each eucalypt species. As the process of subdivisions and development continues, the remaining eucalypt trees, especially on privately owned land, will be under even greater threat of removal. There are no adequate laws

controlling vegetation clearing on private land in Tasmania (Brereton, 1996) and the reasons for tree cutting given by Mount Nelson residents in the survey (i.e. inconvenience of having large trees on the property) were not always justified by safety measures. Therefore, there is a strong need for better environmental laws protecting large eucalypts on private properties.

Bushland preservation alone does not ensure retention of foraging habitat for the Swift Parrot in Mount Nelson. It is paramount to extend the conservation efforts put into maintenance and enhancement of the large bush areas of Mount Nelson, and combine them with protection of suburban eucalypts (including those on private land), as both of those contexts are important in breeding of the Swift Parrot; with large suburban trees providing a reliable foraging habitat and bush trees supporting nesting hollows. Effective management should be also backed up by research, for example, in order to determine social values, attitudes and needs of the community (Low, 1991), as well as understand the natural ecological processes operating within the remnant vegetation of Mount Nelson. Scientific knowledge is required to better understand urban ecology, and support management decisions and on-ground actions in effective conservation of human-altered environments (Garden *et al.*, 2007). A large part of the current scientific knowledge is based on undisturbed habitats (McDonnell, 1997) and non-urban ecological research, which 'hinder the long-term success of existing and proposed urban conservation actions' (Garden *et al.*, 2006, 127). Finally, since there is a lack of accurate and reliable data on the current numbers of eucalypt trees on private properties, as well as trees that have been already lost, increased importance should be placed on maintaining the current inventory of the remaining trees within the privately and publicly owned land, in order to better understand the extent of tree loss in the future and to prevent negative consequences of such loss.

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Appendix 1- Questionnaire

School of Geography & Environmental Studies

Private Bag 78 Hobart

Tasmania 7001 Australia

Telephone (03) 6226 2463

Facsimile (03) 6226 2989

Dear Mt Nelson Resident,

My name is Marta Piech and I am a postgraduate student of the University of Tasmania. I am conducting a survey of large trees in Mount Nelson which will constitute an important part of my current research project. The project looks at the significance of large trees in Mount Nelson as habitat for various vertebrate species, including the endangered Swift Parrot.

I would be very grateful if you could answer a couple of questions regarding large trees on your property. The questionnaire is anonymous and your personal details are not requested. However, question 12 asks for your address. This information will help calculate the proximity of your garden to native bush. Your address will not be published in any way. Also, this project has received ethical approval from the Human Research Ethics Committee (Tasmania) Network. For details, please see attached information sheet.

The questionnaire should take no longer than 20 minutes to complete. Once you have answered all the questions, please forward the questionnaire to me in the self-addressed enclosed envelope.

If you would like a summary of the results of this study, please tick the box in question 13 and I will send you a report as soon as it becomes available. Also, if you have any comments or questions, please feel free to contact me mapiech@utas.edu.au.

Thank you for your time. I appreciate your cooperation.

Sincerely,

Marta Piech

Note before you start: For the purpose of this particular study, a tree is considered to be large if its circumference (measured at 1.3 m above ground) is 2 m or more.

Q1. Please tick one:

☐ I am the owner-occupier of a Mt Nelson property

☐ I am renting a Mt Nelson property

Q2. Do you have any large eucalyptus trees on your property?

☐ Yes (Go to Question 3) ☐ No (Go to Question 7)

Q3. Do you have any large **blue gums** *(Eucalyptus globulus)* on your property?

☐ Yes (Go to Question 4)

☐ No (Go to Question 5)

☐ I'm not sure (Go to Question 5)

Q4. How many large **blue gums** *(Eucalyptus globulus)* do you have on your property (if the number is more than 10, can you estimate how many?)

_____

Q5. Do you have any large **black gums** (*Eucalyptus ovata*) on your property?

☐ Yes (Go to Question 6)

☐ No (Go to Question 7)

☐ I'm not sure (Go to Question 7)

Q6. How many large **black gums** (*Eucalyptus ovata*) do you have on your property (if the number is more than 10, can you estimate how many?)

_____

Q7. Have you had any large trees removed from your property in the past 5-10 years?

☐ Yes (Go to Question 8) ☐ No (Go to Question 9)

Q8. How many large trees have been removed from your property in the past 5 -10 years and what species were they? (i.e. 1 x blue gum, approx.4 x black gum, 1 x name unknown, etc)

_____

_____

_____

(If you're not sure what the exact number was, please estimate how many. If you don't know the name of the species, write 'name unknown")

Q9. Are you planning on having any large trees removed from your property in future?

☐ Yes (Go to Question 10 & 11)

☐ No (Go to Question 12)

☐ Not sure (Go to Question 12)

Q10. Can you name the number and species of the large trees to be removed? (i.e. 1 x blue gum)

_____

_____

_____

Q11. Briefly state the reason(s) why you want to have the tree(s) removed.

_____

_____

_____

Q12. It would help to know your location. If you are not comfortable with providing your street number, then could you please provide your **street name** and tick one of the **areas** below.

Address:_____

_____

Areas:

☐ The Bends

☐ Mt Nelson Primary School area (between the Mt Nelson Water Reservoir at the top of Bend 7 and Mt Nelson Store)

☐ Signal Station area (between Mt Nelson Tavern and Signal Station)

☐ Mt Nelson Oval area (between Mt Nelson Tavern and Mt Nelson Store, including Rialannah Rd)

☐ Hobart College area (between Mt Nelson Store and beginning of Proctors Rd)

Q13. Please tick the box below if you would like a summary of the results forwarded to you. Please note that if you tick the box, you need to provide your postal address (see Question 12)

☐ Yes, I would like to receive a summary of the results

Thank you for completing the questionnaire.

Please forward the questionnaire to the following address using the self-addressed envelope:

Attn: Marta Piech, School of Geography and Environmental Studies, University of Tasmania, Private Bag 78, Hobart TAS 7001

Information sheet for a study of large trees in residential Mt Nelson

Marta Piech and Dr Emma Pharo, of the School of Geography and Environmental Studies, University of Tasmania

We would like to invite you to participate in a project about large trees on residential land in Mt Nelson. This is a Masters coursework project, the primary aim of which is to explore recent removals and people's intentions for large trees on their property.

Purpose
The study is looking at characteristics of large trees in the streetscape, Hobart City Council land and Hobart College land in Mt Nelson. To complement the ecological study that investigates flowering, maturity and health of these large trees, we are seeking input from residents of Mt Nelson about the large trees on your properties, including recent removals and any intentions to remove trees. This investigation is independent and we have no vested interest in the outcomes.

Benefits
The information generated in this study will give us information about how many large trees exist in Mt Nelson, both on your private land as well as Council and Hobart College areas. It looks at the relative health of street trees versus those in the bush. The conclusions from this questionnaire will form part of Marta's Masters thesis.

Selection
You have been chosen as a participant because live in Mt Nelson. If you are not an owner-occupier, we would appreciate you answering the questionnaire as best you can, noting that recent history and decisions about the property are not necessarily easy questions to answer.

Procedures
Your participation is entirely voluntary. Fill out the questionnaire at your leisure and post it back to Marta Piech in the envelope provided.

Anonymity
The only identifiable information that would be helpful is your address. If you do not want to include your address, please note which of the five areas you live in. Given that the information you are likely to be sharing is not of a controversial or harmful nature, the risk to you is minimal.

Confidentiality
All data collected during this project will be kept in a locked room on university premises for the duration of the project for a period of five years after the publication of results. Any collated data will be stored on password-protected computers. Only the researchers will have access to these data.

What if I change my mind about being involved?
Participation is entirely voluntary. You may decline to answer any question.

Has this research been approved by an ethics committee?
The project has received ethical approval from the Human Research Ethics Committee (Tasmania) Network which is constituted under the National Health & Medical Research Council. The Committees under the HREC (Tasmania) Network use the ***National Statement on Ethical Conduct in Research Involving Humans*** to inform their decisions. The Pro-Vice Chancellor for Teaching and Learning and the Director of Human Resources have both given their support to the study by agreeing to send this request to you on behalf of the researchers.

Who can I contact if I have any concerns?
If you have any concerns of an ethical nature or complaints about the manner in which this project is conducted, you may contact the Executive Officer of the Human Research Ethics Committee (Tasmania) Network (human.ethics@utas.edu.au).

Who do I need to contact if I have any questions about the research?
Please contact Dr Emma Pharo on 6226 2049 (Emma.Pharo@utas.edu.au) or Marta Piech on (mapiech@utas.edu.au) if you have any questions about the research.

Am I able to find out about the results of the research?
Please contact Marta Piech if you wish to be informed about the results of this study.

Thank you for taking the time to read this information sheet. Your participation is appreciated and the information you provide will be important to the University.

Marta Piech and Dr Emma Pharo
School of Geography and Environmental Studies
Tasmanian Institute of Agricultural Research

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